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THE NEW HYGIENE

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THE MACMILLAN CO. OF CANADA, LTD.
TORONTO

THE NEW HYGIENE

For Schools of Nursing, Normal Schools, and Colleges

BY

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WITH AN APPENDIX, CONTAINING

"A SHORT COURSE IN MODERN PUBLIC HEALTH"

BY THE SAME AUTHOR

New York

THE MACMILLAN COMPANY

1924

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Set up and printed.
Published July, 1924

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Printed in the United States of America by
J. J. LITTLE AND IVES COMPANY, NEW YORK

PREFACE

This book is primarily an attempt to give to students of Hygiene, whether nurses or teachers, present or prospective, such an understanding of the principles of operation of their own bodies that they may know something of the art of living their own lives well, with comfort and efficiency; and secondarily, an attempt to so give this understanding to the nurse and teacher that they may in turn teach the same art to their respective charges.

The student should aim to learn Hygiene, not from the text alone, but by the practice of that which the text sets forth—to learn by the only real method of learning—"learning by doing." This book does not aim so much at telling the student what to think as what to think about. Mere memorizing is fatal; the assimilation of ideas is the one way to education; and this assimilation can be achieved only by the practical application of the ideas in real life. The student who has learned principles, but has never applied them, is not yet fit to teach those principles. Students of Hygiene have exceptional advantages in learning applications, for they always have *themselves* available to themselves as practical problems; and may easily reach out for more problems among their associates, their communities, and their countries.

Because Nutrition is the first of the arts of living developed by the individual, who as a newborn infant can do little else than feed; and because Nutrition is of the very first importance then and thereafter to his success in life, human Hygiene begins with the new-born infant and with Nutrition.

Protection is the next art of Hygiene in chronology and importance, because it is some time later that the child becomes able to care for itself and to develop the protective arts against invaders.

Only in after years does the new individual become fitted for what biologically is known as reproduction, but which properly includes not alone begetting new individuals, but what is more important, providing for them the necessary surroundings, care and training on which racial continuation is necessarily based. These three—Nutrition, Protection, Reproduction, or better, Race Maintenance—broadly considered, constitute all those ceaseless, growing, developing activities which make human life possible and maintain man as the supreme race on the globe.

In this order Nutrition, Protection, Race Maintenance—the order of importance, the order of chronology, the order of the needs of man—Hygiene, the art of living, is here presented. This order is but the scientific exposition of the very commonplace and very human phrase which humanity has evolved as epitomizing the same needs—"Board, lodging, and a job."

Hygiene, then, is the combination of arts of carrying on the physical life thus epitomized, with the maximum of required returns from the minimum of necessary expenditure. It is by no means a mere recital of the normal functionings of the human body; rather it is the art of driving the human machine comfortably and efficiently, with a definite purpose. This purpose is to accomplish in the driving whatever most worth while in life may be selected as its goal.

Acknowledgments for material used are inserted in the text where such acknowledgments are possible. But most of the facts given are common property to all students of Public Health and its allies; and the ways of looking at the facts herein outlined are matters of gradual develop-

ment, shaped by a thousand touches here and there, the effects of which remain after their specific origin has been lost sight of—if indeed it were ever consciously appreciated.

To one faithful and conscientious, most painstaking and acute critic, the fullest acknowledgments are due—Sister M. Domitilla, B.S., R.N., Educational Director, School of Nursing, St. Mary's Hospital, Rochester, Minnesota—whose collaboration took the further forms of preparation of the projects appended to the various sections, and of the Teacher's Guide which presents in projects the practical conduct of classes in Hygiene.

Most grateful thanks are also due to Miss Jennie Fidlar, Dr. F. W. Luney, and Professor F. R. Miller, all of London; to the former for valuable literary criticism and efficient proofreading; to the two latter for technical criticisms and suggestions, each in his own field; respectively, Immunology and Physiology.

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THE NEW HYGIENE

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THE NEW HYGIENE

CHAPTER I

THE "NEW" HYGIENE

Hygiene is a term which, as it is at present used, lacks any very clear-cut definition. One recent writer interprets it narrowly as dealing with *minute personal cleanliness;* another goes to the other extreme, making it broadly synonymous with *all public health.* Still others include under it such incongruous items as taking ten deep breaths a day, the administration of child welfare clinics, the proper way to hold a kerosene lamp, resuscitation of the apparently drowned, and how to take ink-spots out of aprons. Exact references can be given, but would perhaps be invidious.

Yet if one studies carefully the chaotic uses of this orphaned term, even in the most chaotic of the literature written under the caption of Hygiene, it will in time dawn upon him that the term is after all more or less consistently employed, although this consistency is often somewhat unconscious—rather the result of instinctive groping than of deliberate selection. Whenever a writer proposes to treat of the living body rather than of its surroundings, and especially if he proposes to treat of the *untechnical, personal* care which the ordinary individual may give to his own body, rather than of the technical professional care which doctor or nurse may give to the bodies of others, he

calls his material Hygiene. We may be allowed to condense our literary findings thus—Hygiene, "as she is spoke," usually concerns *the non-medical care of the living body.*

Since then, Hygiene has the living body for its central theme, and although *all* public health is becoming more and more recognized as a biological rather than a physical or chemical or mechanical subject, Hygiene is preëminently *the* biological subdivision of public health. As we shall see, the new Hygiene is truly, at bottom, *the practical study of the potentialities of living protoplasm.*

To place Hygiene as definitely as possible amongst its fellows, one may venture a well-worn illustration once more. Thus, treatises on the body may be compared with treatises on the automobile. The *anatomy* of the body will then correspond with descriptions of the various *parts* of the automobile *at rest;* its wheels, radiator, crankshaft, carbureter, etc.; their shapes, sizes, compositions, and the ways in which they are set together. The *physiology* of the body corresponds with the story of the various parts of the automobile *in action,* when the automobile is running; hence, with the revolutions of the wheels, the circulation of the water in the radiator, how the crankshaft acts and what it accomplishes, the history of the gasoline from its introduction into the tank to its ejection as waste-products through the exhaust. The *pathology* of the body corresponds with accounts of the defects and injuries which the parts of the automobile may suffer; and with the long list of incoördinations in the smooth operation of the parts with each other which, when they occur, interfere with the efficiency of the automobile or even wreck it. The *therapeutics* of the body corresponds with the lore of the automobile repair shop,—how to patch a tire, or replace a broken hub, how to stop a radiator leak, or to tighten a slipping fan belt, what to do with a worn-out bearing, or a plugged carbureter needle, how to adjust a

missing magneto, or detect and replace a cracked spark-plug.

Hygiene, in distinction from all these, corresponds with the science and art of *driving the automobile as a whole;* it is concerned with anatomy, physiology, pathology, therapeutics, etc., only as these may aid the main issue, the operation of the body efficiently, comfortably, for as long as possible, and with the attainment of the chief ends of life, whatever they may be. True, just as the expert chauffeur must know something, the more the better, of the "anatomy" of the automobile, its physiology, pathology, therapeutics, etc., if he would do long distance driving to the best advantage so the structure, functions, diseases, and repair of the body should be at least in principle known to the hygienist if he would conduct his body well through the world for sixty or seventy years.

But just as many an automobile driver drives very excellently without such an intimate knowledge of the details of his machine as would properly be exacted from the repairshop man, so the human body in health may be managed well by one who is not an expert in human anatomy or physiology, pathology or therapeutics.

Nevertheless, as the best chauffeurs are in the long run those who have taken pains to learn their machines inside as well as out, so the best drivers of the human machine are those who have intelligently studied the make-up and operation of its parts, as well as of the whole.

Hygiene, then, in this parable, concerns itself with the driving of the human machine; each individual hygienist, after proper training, acting as chauffeur of his own body.

So much for the general field which the term hygiene more or less indefinitely covers in the literature up to date.

What, then, is the "new" Hygiene? Of course, it naturally covers the same general field as the old—the care and operation of the living body, as a whole. But it differs

from the old in several rather important features. First it considers the *body;* and the surroundings only as they affect or are affected by the body. The older Hygiene, although the body was also its central theme, yet often—perhaps it is fair to say, generally—neglected this central theme to deal instead with the effects on the body of its immediate surroundings, to inculcate avoidance of dangers to the body inherent in the surroundings, to describe and insist on the care and control of the surroundings. Thus clothing, although clearly a part of the surroundings, not a part of the body, was considered in the greatest detail. Yet this subject certainly belongs to sanitation, quite as must as do the subjects of air, or water, or food supplies, all admittedly sanitary subjects. It is true that clothing comes very intimately into contact with the body, but so do air, water and food. Moreover, clothing comes into contact with the outside of the body only, while the others come into contact with the even more important inside. The cleansing of the teeth is also usually treated of as Hygiene; but at what point is the cleaning of the teeth to be differentiated from the cleaning of any other part of the body, the washing of clothes, of the dinner dishes, of the vegetables that enter into the dinner, the purification of the drinking-water, the pasteurization of the milk? Scientifically, logically, these are all equally concerned with protecting the body by dealing with its surroundings. Hygiene deals with the *reactions of the body to its surroundings,* whatever they may be. Hence, one characteristic of the new Hygiene is the making of a clean-cut discrimination between the body, with its great potentialities, on the one hand, and the universe outside of the body, on the other hand.

Second, the new Hygiene, in its consideration of the body, does not dwell so much on its ordinary limitations, its shortcomings in dealing with its surroundings, as it does on its extraordinary potentialities to meet its sur-

roundings and changes in them. The new Hygiene recognizes the biological fact that life has become what it is today, the most wonderful thing in the world, *by the adjustment of life to things,* rather than by the adjustment of things to life. The older Hygiene looked upon the body as the rather helpless plaything of its immediate surroundings, not as a powerful, reacting force, which deals strenuously with its surroundings and in time conquers them. It was just this attitude of the earlier hygienists which led them to treat of the immediate surroundings of the body so minutely—to prescribe all sorts of anxiously set limits for the surroundings, to warn against calling on the body for any great reaction to them. This gave rise to the laying down of rigid ceremonials to be conducted daily, hourly, minute by minute, in order that the body might be guided safely between and among the numerous pitfalls ever lying in wait for the ignorant and careless. "Simple rules of health" dealt with wet feet, closed windows, forgetting one's muffler, eating red meat, and a thousand other "taboos," constituting a *negative* "code" of Hygiene, strikingly like, in principle, the Old Testament rules of morality. True, another and much more recent Hygiene professed itself as *positive* and aimed frankly at "building up the bodily resistance." By diet, sleep, exercise, free excretion, and a cheerful frame of mind, it proposed to so arm the body aggressively against "the slings and arrows of outrageous fortune" that it might smile in superior disdain at the defects, disabilities, disease and death that other mortals suffered. Although a step in advance over the negative "do-not" Hygiene, it was also a step sidewise from the truth, and collapsed as a whole and in each of its several parts whenever it or its professors encountered that greatest factor in disease and death, infection. Our most highly trained athletes in our civil life, our soldiers in the great war, our whole people during the influenza epi-

demic, demonstrated by succumbing to infection on every possible occasion, that such "resistance" was not resistance to infection—that such resistance, whether cultivated against food, fatigue, cold, or heat, was a resistance *to that thing,* not to something else. A most perfect diet and digestion, with every item going well in the nutritional line, does not itself cultivate the ability to run a mile without fatigue; nor, conversely, does the ability to run a mile without fatigue cultivate the ability to digest and assimilate food; much less can either one or both together prevent infection with disease germs or secure resistance to their poisons. Only body immunity, secured by encountering and overcoming the poison of each germ separately, can supply the resistance to that germ. The new Hygiene, in definite agreement with the resistance school, recognizes the "building up of resistance" as the great aim of Hygiene; but, in definite contrast with this school, recognizes also the great *specificity* of the body resistances. It maintains that the resistance to any given invader, be it cold or heat or germ, can be built up only by encountering *that invader,* not some other one; and, once so built up, that resistance is of avail against that invader, *and that invader only.*

A striking illustration of the principle just stated is found in the fact, well known to every one who has ever had to do with smallpox, that practically every one, prince or pauper, athlete or invalid, born into this world, will contract smallpox on exposure to it for the first time. No diet, sleep, exercise, or other regimen ever devised will protect against the disease. But, having once had smallpox, or its mild form, vaccination, the body, after recovery, is found to have had its "resistance" so "built up" to smallpox, that the closest and most prolonged contact with smallpox will no longer have the slightest effect. But this resistance, so perfect to smallpox, does not ensure its possessor against any other ill. As diet, sleep, exercise,

etc., fail to produce resistance to smallpox, so resistance to smallpox fails to ensure against indigestion, insomnia, fatigue, or indeed against anything else in all the wide world except smallpox. Now these striking and world-wide established facts concerning smallpox do not constitute a curious exception to the rules of life; rather the new Hygiene recognizes that they constitute *the* rule on which *every* resistance of the body to every outside influence is based.

But the new Hygiene does not rest content with thus recognizing the enormous potentialities of the body, their obvious limitations, the invasive forces of the surroundings, and the ability of the body to "build up" *specific* resistances to them. It does not lament the need for building up resistance, nor look upon this dire necessity as just one more restraint on life. Rather, the new Hygiene sees in these abilities the great means of advance—not a burdensome armor against the universe, but a keen weapon by means of which living protoplasm can, not merely escape from, but seize upon and assimilate to its own uses all its surroundings. This latter is not done without effort, pain, and some inevitable failures, truly; but on the whole we may, through these principles, speed up that development of our protoplasm to meet the demands of our surroundings; speed up those abilities for adaptation of the individual and of the race to which we owe our present state of development, and which, even in the absence of understanding and intelligent coöperation on our part, have nevertheless brought us this far very successfully, if very slowly. The new Hygiene does not look, like the ancient astrologer, to the far-off stars for help or hindrance; nor like the older hygienists to an intimate defensive struggle with the much nearer environment of air, water, food, and other things. Rather it turns its eyes in upon the body itself which is the central nucleus of the whole problem. It is in the abilities of the body

that the new Hygiene finds the great forces of life; the surroundings are but the tools by which these abilities may be elicited and developed.

These are brave words, and it becomes us in all humility to grant most freely that we are but on the threshold of this new conception. It has been growing at the hands of many workers, here a little, there a little, until at last we may roughly formulate it somewhat as above. Returning to our comparison of a treatise on the body with a treatise on the automobile, we must realize that there are an immense number of things going on in the body about which we at present know little or nothing; and that there are an immense number of things in the body—far more numerous than in the automobile—about which we know more or less, but which are wholly automatic, and quite outside of our direct control, such as the beating of the heart, the circulation of the blood, the secretion of the various glands, *ad infinitum*. Most of us cannot pretend to understand or direct these automatisms of the body, as our best automobile engineers may understand, direct, even improve on, or substitute other devices for, the various automatic mechanisms of the automobile. Only our greatest physiologists, our most expert physicians, can really understand, and sometimes partly control, these intricate bodily mechanisms.

Hygiene is, or should be, applied physiology. Unfortunately, much of the physiology of the present day is devoted to determining the status of a standardized body, towards which the physiologist consciously or unconsciously works, an attempt to discover what the body does, rather than what it may do. The experimental animal, which under the conditions imposed by the experiment gradually adapts itself to the circumstances, is looked upon with disfavor, as hardly playing the game, and is more than likely to be rejected, as spoiled by his adaptation! Yet that very ability to adapt is the most interesting and

important feature of life. A few physiologists, be it said, notably Sedgwick and Leonard Hill, have really used physiology as a stepping-stone to hygiene; but the vast mass of the physiology of today is barren and academic, rather than practical and applied. We know infinitely more of the lore of the repair-shop—therapeutics—than of the art of driving which is Hygiene.

Finally, just as we would doubtless end our automobile treatise with exhortations to the unprofessional driver not to attempt the readjustment of his own automobile on the mere strength of what he has read, so we would exhort all beginning students of Hygiene not to meddle, unsupervised, with the automatic adjustments of their own bodies. Just as we would beseech the young automobile driver not to meddle on his own account with his carbureter, and to get expert advice before readjusting his magneto, so the hygienist must warn his readers against similar "monkeying with their own works." On the other hand, we each of us have our own body machines, which, willy-nilly, we must somehow drive, each on our own hooks, through the world. Certain things the automobile driver must do for his machine, however little he may know about its interior economy. He must provide oil and gasoline; and he alone can and must regulate the supply of the latter, if he would drive at all. Just so each human mind must, sooner or later, and to some extent concern itself with provision of air and food for its body, and regulate in some degree the supplies of each to the body, day by day, or moment by moment. In these and a few similar kindred matters, we are justified in teaching and in expecting some practice of the general principles involved.

Fortunately, there is one striking difference between the automobile and the human body—the latter is by far the most standardized machine, far tougher, more stable, and much less likely to be injured seriously by even the most

inexpert meddling. Else had the human race long since vanished from the globe. Also, the human body, unlike the automobile, suffers pain when maladjustments are made, and this itself is a great safeguard against undue interference, against inept experiments. Once again, the body exceeds the automobile in its extreme adaptability. Hence tasks laid upon it that at first upset its existing status, even to the point of pain, often elicit from it reactions hitherto latent; so that pain is rather a sign of imposing the new task too abruptly than of a total inability to meet it at all.

Lastly, be it said here, however unnecessarily, that in all that is written here concerning life, it is the physical life —the life we know of in living protoplasm, whether of ameba, whale, man, or turnip—that we write. Conceptions of mental, moral or spiritual life are not included or even referred to. We realize fully that mental hygiene is immensely important, and that it is developing slowly to be the great immediately pressing and practical hygienic problem of today. But the task of writing on this subject is beyond the ambitions of this small volume with which, if it conduces to a clearer view of physical Hygiene, we shall be more than content.

CHAPTER II

DEFINITIONS AND RELATIONSHIPS

Much of the haziness obscuring Hygiene and the allied subjects connected with it is due to mere confounding of the names of the different recognized fields. Therefore, in beginning the study of Hygiene, it is quite essential to secure at the very outset sufficiently sharp-cut ideas of these fields and of the names used for them to ensure that both student and teacher mean the same thing when they use the same word.

Allied Subjects

In order to do this well, it is needful to know what Hygiene is, and also what it is not; how it differs from and how it relates to these allied subjects; and therefore something of the allied subjects themselves, what they are, why they exist, their character, their scope, and how they differ amongst themselves and from Hygiene.

These allied subjects, often vaguely confused with Hygiene, are Physical Welfare, Health, Public Health, Preventive Medicine, Sanitation, Epidemiology, and Therapeutics.

With their subdivisions and correlatives, these eight (including Hygiene), constitute the immensely important section of *applied* human biology in its broadest sense. Each of the eight presents at least five different aspects, scientific, technical, administrative, sociological, and

humanitarian. Thus at least forty methods of approach to these fields exist, each of which attracts certain minds according to previous training, habits of thought, "bent," or mere accident.

Of these eight terms, Physical Welfare is the most comprehensive, since it is descriptive of the ideal end sought, which end is the securing of high health in the body, *and also* the best of surroundings for the body. Health is an end also, but is a less inclusive term, for it applies to the body only, and implies nothing at all about the surroundings.

The other terms, Hygiene, Sanitation, Preventive Medicine, Epidemiology, Therapeutics and Public Health do not indicate ends in themselves but only various means to the ends, Health and Physical Welfare.

Hygiene deals with the adjustments which the body may make to its immediate surroundings; Sanitation with the adjustments of these immediate surroundings to the body. Preventive Medicine is a highly technical division of Hygiene, concerned with furnishing the body with certain more or less artificial adjustments designed to protect the body in advance against causes of prospective disease in the surroundings; Epidemiology is a highly technical division of Sanitation concerned with eliminating prospective causes of disease from the surroundings, to the end that preventive adjustments of the body to them may become unnecessary. Therapeutics is the special Hygiene and Sanitation of the sick, and is concerned therefore with aiding the natural body adjustments to meet imminent causes of disease—causes already in operation—which it is beyond their unaided powers to meet successfully; or with lessening the action of those imminent causes, to the point where the adjustments, aided or unaided, of the body may be adequate to meet them. All these terms apply to individuals as well as to groups.

Public Health includes all these subjects as applied to the individual and to his surroundings, but deals chiefly with people in the mass rather than as individuals, attempting to secure the highest physical interest of each, but also to so harmonize and correlate those interests, sometimes somewhat conflicting, that all persons, not merely a few, may be benefited. It is the sociological division of Physical Welfare. Although properly speaking it includes the Hygiene and Sanitation of the sick (Therapeutics) as well as the Hygiene and Sanitation of the well, its great field lies in prevention for the well rather than in cure for the sick, the latter requiring forms of individualistic service of quite a different type from that mass service rendered by most Public Health procedures. Public Health, in its applied form, Public Health Administration, does not usually at the present time include Therapeutics.

Constituent Sciences and Arts

The terms above listed are by no means only convenient "subject headings." They each one indicate a field of activity which is distinctive enough to have its own specialists, its own technicalities, its own methods of study, and its own results, as a rule also requiring a special type of mind in its exponents. Thus Hygiene is based on Physiology, the study of the body; Sanitation, on Chemistry, Engineering, Mechanics and Physics, and other studies of the surroundings of the body; Preventive Medicine, on Medicine, Surgery, Pathology, and Bacteriology, applied individually to the prevention of disease; and Epidemiology, on all the foregoing list of sciences and arts, as applied sociologically to the prevention of disease. Therapeutics includes the arts of Clinical Medicine, Surgery, and Nursing, when used to restore health, rather than to prevent disease; Public Health employs all the

other divisions to the end of securing Health and Physical Welfare for the whole race.

Although we usually think of these subjects as peculiar to the needs of the human—and they have of course reached their highest developments in human circles—yet in elemental form they are essential to all life, animal or vegetable, bacterium or whale. Life cannot continue without constant adjustments between the living thing and its environment. These adjustments are for the most part made automatically and unconsciously. The higher we ascend in the scale of mental development, the greater becomes the conscious, purposeful adjustment, until in man we find the intricate, immensely varied and specialized adjustments, particularly those of Sanitation, in modern civilized life.

Illustrations of the Uses of These Terms

Because modern civilized life presents such a complicated interweaving of these subjects, it is worth while for the beginner to spend a little time in tracing the lines of Hygiene and its allies under more simple conditions, and this is perhaps best done by considering the example of a castaway thrown naked upon a desert island.

Our castaway, let us say, is the only human upon the island; he together with his surroundings constitutes a world in miniature. He finds himself dependent for comfort, for health, for life itself, first upon the capabilities for adjustments to his surroundings which he has already or may develop within himself; and second upon the resources of the island as they exist or as he may be able to develop them, *i.e.*, on their adjustability to his needs. The first, the adjustment of his body to his surroundings, is Hygiene; the second, the adjustment of the surroundings to his body, is Sanitation. In so far as he succeeds in the first, he will attain Health; if he succeeds in both, he will attain Physical Welfare.

Hygiene

As, naked and alone, he faces these problems, it will be borne in upon him that the immediate field of action lies in Hygiene, because his body is already adjusted more or less well to its surroundings or he would already have ceased to live, and so long as his body continues to adjust itself to its surroundings he will continue to live. But he also will recognize that the surroundings existing at a given moment are very unlikely to continue precisely as they then are; that changes in, say, temperature alone may be sufficient to end his life, if they exceed the ability of his body to adjust itself to them; and therefore that the limits of the range of adjustment to temperature which his body already possesses are his existing limits of life, so far as temperature is concerned, unless he can control the future changes in the temperature; briefly, unless he can control those changes he is at the mercy of his surroundings.

He may, it is true, discover in his body *hitherto unsuspected* abilities to meet changes in the surrounding temperatures, and therefore that his chances of survival are better than he at first thought. Moreover, he may find that his body, exposed gradually to changes occurring slowly, shows a remarkable ability to *increase* its own range of adjustments. But he will also realize that there will be somewhere a limit to this capability of adjustment; that sooner or later the temperature of his surroundings may become too hot or too cold for his body if his body is left unaided. He therefore will seek some means to modify the temperatures his body will be called upon to meet.

Sanitation

Clothing, shelter, fire, naturally suggest themselves—and these, since they are derived from the surroundings, are of course matters of Sanitation. It is at this point that

the drawbacks due to lack of companions, of associated individuals, become evident. The control and development of his own body is a personal matter which he can manage pretty well alone; but the control and development of his surroundings to an efficient extent he will recognize as an immensely laborious, difficult, and, in some respects, impossible task for one individual. Hygiene then is individualistic; Sanitation, in all but its crudest forms, coöperative, Hygiene finds its highest developments in the lowest forms of individualistic life, Sanitation in the highest forms of coöperative life.

Heretofore, at home amongst his fellows, he has carried on the various functions connected with life without much thought. He has followed almost automatically the customs and traditions of those amongst whom he was born and brought up. He has eaten the usual things at the usual times, dressed in the usual ways, considering little if at all the reasons why or the relations of cause and effect. His baker, his butcher, his tailor, supplied his fundamental needs, and he did not go back of their offerings except perhaps to grumble at their prices. Now anything he can see even remotely resembling food is hanging high on distant trees, flying far through the sky, slipping shadowily through the woods. Anything in the form of clothing which he may need he must likewise obtain himself from the crude materials at present existing as hides of living animals which he must locate and catch, or as vegetable products which he must identify, gather, prepare, shape, and put together. But he has no weapons with which to secure animals for food, no knife with which to cut them up or even to remove their skins, no stove on which to cook them, no fire to put in the stove. Moreover, if he had all these facilities, still there is needed the skill to use them; and finally the aggressiveness of his surroundings must be overcome. Not only must he attempt to wrest from his surroundings the things he needs, but he

must escape the attempts of his surroundings to wrest from him such things as his surroundings need. He is himself good food for other living beings—tiger, wolf, shark, insect, bacterium—all will use him as food if they can. The cold wind takes from him his body heat; the thorn, the cactus, and the sharp stone restrict his attempted movements. Everything he does will fall into one of two groups, as an attempt to secure something useful for himself, at the expense of his environment; or as an attempt to avoid something harmful to himself, which would be an accession to his environment. He must take from his environment food, drink, air, warmth, clothes, shelter, rest, and he must at the same time avoid accidents, poisons, attacks of other animals; in brief he must prey on his surroundings, but he must not let his surroundings prey on him. In the language of Public Health, he must (a) promote his own health (Hygiene) and at the same time (b) prevent "disease" from attacking him (Sanitation). These two correlated divisions are found in every enterprise of Physical Welfare, however simple or however complicated.

Mental Readjustment of the Castaway

This, his first summary of his situation, brings him to see himself as an Ishmaelite in nature, his hand against everything, everything's hand against him. Like a new boy in a strange school, he thinks all is wrong for him, all is antagonistic to him. So doubtless primitive man looked on the great world about him; so the lower savages of today regard their surroundings. Even the most civilized races cannot yet wholly escape something of this attitude. But in proportion to the understanding of himself and of his surroundings which man is slowly attaining, the problem resolves itself into one of coöperation with nature rather than of struggle against nature. The primary fallacy of man's attitude, evolved in the dim mists of his

earliest prehistoric ignorance, still holds many of us in its sway—the conception that man is something apart from nature, something different, something thrust into the chaos as an afterthought. The true conception is that man is as much a part of nature as a stone, a tree, a horse, a wolf; that he comes from nature, and has been shaped by nature. He has therefore the initial potentialities of adjustment necessary and common to all living things—and this is fully demonstrated by the mere fact of his survival. He has perhaps a greater inherent power for adjustment to his surroundings than have other living things; but whether this be true or not he has, far in excess of any other living thing, the ability, especially in association but also individually, to control his surroundings to his own needs.

His ability to adjust his body to his surroundings is his physiological "capital," the accumulated "savings," so to speak, of previous generations, the "going concern" which he has inherited from his parents, and they from theirs, in the long toilsome ascent of the ages. His management, good or bad, of this "capital," his "personal hygiene," the care and skill in operation that he accords his body, decidedly affect his comfort, efficiency, and enjoyment of life, which is the "interest" he can obtain on this "capital." But he can add little if anything to the capital either for himself or for transmission to his descendants; nor can he subtract much if anything from his inheritance of potentialities. Even should he lose a limb his ability to transmit a whole body to his descendants is unaltered. It is this proper management of his physiological capital that we call Hygiene; and it consists in securing the maximum possible correlation between himself and his surroundings. To do this involves not only study of his own potentialities, but also study of the surroundings with which he must correlate them, and therefore Hygiene cannot be considered wholly apart from Sanitation.

Hygiene versus Sanitation

Such distinctions may sometimes seem trivial, for our castaway is acting as a Hygienist when he decides that the cold is too great for his body to meet unaided, and as a Sanitarian when he seeks shelter. In the separate study of the subjects the distinction consists in this: in the study of Hygiene, we assume certain surroundings and describe the action and operation of the body suitable to those surroundings; in the study of Sanitation, we assume the action and the operation of the body, and describe the surroundings and their modifications suitable to its actions and operations.

Thus in treating of the Hygiene of the body related to water, we consider the needs of the body for water, the uses which the body may make of water, the operation of the body in the presence of excess or deficient water, the reactions of the body to impure or otherwise unsuitable water, and similar topics. But in treating of the Sanitation of water, we consider the sources of water, the amount available, how to obtain it, its purity, purification, protection, and cognate matters. Thus it often happens that the Hygienic expert, although thoroughly familiar with and an authority on the *uses* of water in and for the body may be quite incompetent to deal with questions of public or private water *supply;* and on the other hand, that the Sanitarian, fully conversant with every phase of the often very intricate problems of water supply, may be only superficially familiar with the chief questions concerning the uses made of water in the body. Hygienists have recently completed prolonged and intricate experiments on the requirements of the body in relation to heat, humidity, and circulation of air, and on the adjustments which the body may make to changes in these factors. But Sanitarians have not yet devised and realized in everyday life

those necessary changes in the ordinary surroundings of the masses of the people that would make these factors readily and practically controllable. Hygiene must always furnish the chief initial data to guide Sanitarians, for Hygiene deals directly with the needs and capabilities of adjustment of the body, and it is to secure the most successful operation and conduct of the body that both Hygiene and Sanitation exist. The duty of the Hygienist is to consider all the many various circumstances and conditions which the body may encounter at any and every period of life, to determine how far the body can with success meet these by its own adjustments, and to suggest modifications in the surroundings which, when the body's limits of adjustment are reached, may hold the requirements of the surroundings below those limits. The duty of the Sanitarians is to consider the same many and various circumstances and surroundings in relation primarily to the needs of the body, and to study those surroundings with a view to securing the modifications, if any, needed by the body.

Involuntary Hygiene

To make these ideas as concrete as possible, let us suppose that a cold wind comes up while our castaway is mournfully contemplating the dismal prospect before him. Without clothes, fire, or house, he shivers, and panic-stricken runs along the beach, hoping to find a sheltered spot. But as he runs he grows warm, and stops—to laugh. He has found a resource of Hygiene—a method of increasing his own internal heat production that makes him, to an extent, independent of his surroundings. He now realizes that his body has been unconsciously adapting itself to the increasing cold even while he stood quietly thinking about his situation—an automatic and quite involuntary adjustment with which his own initiative had

nothing to do. When the limit, for the moment, of this involuntary, unconscious, automatic adjustment had been reached, the discomfort following its unsuccessful attempt to meet the still increasing cold caught his conscious attention; when he ran, he secured a further output of heat by a voluntary, conscious, purposeful action, not, it is true intended to warm him, but which nevertheless and incidentally yielded a by-product of warmth. Hereafter he will use this discovery definitely for the purpose of warming himself—as a form of voluntary Hygiene.

Voluntary Hygiene

But there are certain drawbacks to such voluntary forms of Hygiene. The automatic adjustments to changing temperature which his body makes, even at rest, are by no means the only automatic adjustments which go on. The rates of his heart beats, of his breathing, of his output of perspiration, also change as the temperature changes. When he runs, a voluntary action, his heartbeats, breathing rate, perspiration output, incidentally increase; they increase without his order, quite independently of any knowledge or foresight of his own. Such automatic adjustments constitute an involuntary Hygiene which the body supplies, and of course has supplied through the ages, before mankind thought consciously of them at all. Suppose that before running, one had to calculate and to decide just how many heartbeats per minute one must produce, how many breaths one must draw, how much perspiration one must secrete, for a given speed, and grade, and weight of body, clothing, etc., having due regard also to the temperature and humidity of the air, and many other factors! These are but three of the more obvious of very many adjustments which his body automatically makes when he runs. Thousands of similar and other adjustments occur daily as the automatic response of the

body to the thousands of changes in the movements and surroundings of all of us. Most of these are beyond our direct control, as is the heartbeat. A few, like breathing, are under control to a limited extent. The majority may be elicited or put into action, voluntarily, only by the indirect method of subjecting the body to those conditions of motion, temperature, etc., to which the body will respond automatically. Thus by running more heat may be produced. But not heat alone; increased heart beats, breathing rate, perspiration, are elicited also, unavoidably. Hence this form of voluntary Hygiene is only possible or even advisable when not only the particular object sought —in this case heat—is advisable, but also the correlated by-products—in this case increased heartbeats, breathing rate, and perspiration—are possible or advisable also. Running to keep warm is not a method open to every one, but only to those whose hearts, lungs, etc., are capable of making the correlated adjustments. Moreover, the most perfect body cannot maintain for any great length of time the high rates of heartbeat, etc., required by continuous rapid running. Thus, in such voluntary Hygiene, we must recognize a positive form, consisting in eliciting an adjustment we require; but also a negative form consisting in avoiding the eliciting of an adjustment, the eliciting of which involves the making of other adjustments of a harmful nature or to a harmful extent. A third and very attractive form of voluntary Hygiene, which may be called the aggressive form, consists in measures leading to an increase in the ranges of the adjustments which the body can make. These latter measures in general have one common characteristic in that they involve the use of the very adjustment the range of which it is desired to increase; in general another common characteristic, in that this use of the adjustment must be alternated with disuse, or rest; a third, in that the use of the adjustment can only be called forth by exposing the

body to those surroundings to meet which the adjustment exists; and a fourth, in that the severity of those surroundings—the demand on the adjustment—must in general be only slowly and gradually increased. Thus, a blacksmith's apprentice envies his master's ability to hold very hot iron, barehanded, without pain or damage. Perhaps, if uncommonly ignorant, the apprentice tries to "harden" himself by washing his hands in cold water, going without gloves in cold weather, exercising his muscles, eating beefsteak, or doing other things he sees his master does. But sooner or later the apprentice finds that, whatever these things accomplish, they do not increase his ability to *handle hot iron painlessly*. In order to develop *this* specific ablity—an adjustment of his hands to hot iron—he must deal specifically with the heat—nerve—endings in his hands, and deal with them by exposure to heat from hot iron, not by exposure to cold, nor to water, even though it be hot.

But he cannot at first handle iron as hot as his master can, nor can he hold even cooler iron as long. He must be content to begin by holding relatively cool iron for relatively short periods, or suffer blisters and pain. But by degrees he finds the intervals of rest he requires are growing shorter, the periods of holding he can stand are growing longer, and he can also handle thus iron much hotter than he could manage at first. Finally, he equals his master in this particular, or even excels him. By like means, the ranges of other adjustments of the body can be developed to an astonishing extent, varying widely, it is true, in different individuals, as witness some of our spectacular athletics and games, juggling, prize-fights, etc. It is well to remember, however, that such extreme developments are not by any means always of ultimate benefit to the bodies in which they have been developed.

Health

Health may now be seen as that condition in which the body is when meeting successfully all the requirements of the surroundings to which it is exposed. Those surroundings may call, it is true, for adjustments the maintenance of which for long periods may exhaust the body, as for instance, in the case already quoted, of running to keep warm. Indeed, it may be said of every adjustment of the body, voluntary or involuntary, that continuous demands without rest periods will exhaust them. But *so long as* the requirements are successfully met, *health* exists. Health is therefore a condition which may be very temporary, existing merely moment by moment, while (a) the ability to adjust exists, (b) the demand for the adjustment is not excessive, (c) the demand for the adjustment is not too continuous. Health differs from Physical Welfare, inasmuch as the latter term indicates not only a situation in which the body is meeting the demands of the surroundings successfully at the moment, but also such a favorable situation in the surroundings that those demands can be met by the body for indefinite periods. This by no means implies that the arts of Hygiene or of Sanitation aim at a fixed set of idealized conditions under which once they are established, we may "live happy ever after." Such fixation of our surroundings is not possible except under extraordinary circumstances, usually experimental; and if it were possible, would probably be ultimately disastrous, because it is not at all unlikely that if the need for adjustments were thus done away with, the ability to adjust would ultimately be lost, or minimized. Continuous changes, but within the limits of body adjustment, are essential to the highest form of Physical Welfare.

Disease

What then is disease? Disease (dis-ease, broadly speaking, is that condition in which the body is when meeting unsatisfactorily any requirement of the surroundings, external or internal, to which it is exposed; that is, when the adjustment called for fails or is made only with pain or damage. The casual impression that disease is necessarily a desperate condition in which the body hovers between life and death is a conception which applies only to a very advanced stage of disease—the only stage of disease which was at one time seriously considered at all. We now see that disease may exist in the mildest as well as in the most severe forms, that most severe attacks begin with almost imperceptible difficulties in adjustment; that it is at this stage that correction of the maladjustments are most likely to be successful; and that therefore the recognition of and prompt action in the early stages of disease constitute the fundamental principles of *cure;* while an intimate knowledge of the hygiene and sanitation of the body, combined with a keen foresight which will recognize prospective causes of disease before they begin to operate, constitute the fundamental principles of *prevention.* Personal Hygiene devotes itself chiefly to the care and cultivation of those adjustments of the body which are concerned in meeting the *quantitative* changes in the ordinary surroundings of the body; in those surroundings which, like temperature for instance, are inherent and ever present in all parts of the universe. Preventive Medicine, as one branch of Hygiene, devotes itself chiefly to the care and cultivation of those adjustments of the body which are concerned in meeting *qualitative* changes in the surroundings of the body, those which, like disease germs, are not constantly present everywhere or may even be very rare. Sanitation, conversely, devotes itself chiefly to the control

of *quantitative* changes in the ordinary surroundings of the body, in order to hold them within the ranges which the body adjustments can compass, while Epidemiology as one branch of Sanitation devotes itself chiefly to the control of those *qualitative* changes in the surroundings to which the body may have no adjustment abilities, or inadequate ones. The causes of specific diseases are qualitative changes; for instance, the causes of lead poisoning, x-ray burns, lightning stroke, smallpox, etc.

Health and Disease

Thus Health and Disease are not opposites, not distinct entities, not wholly unlike, not even incompatibles. They are, in their well-developed forms, merely the two ends of the same scale; a scale which is graduated so minutely from perfect health to death that the intervening steps taken consecutively may be almost unrecognizably small. Positively considered the scale is one of success in adjustment to the surroundings imposed; negatively considered, it is a scale of escape from pain or damage. Each gradation is the resultant of (a) the ability of the body at a given moment to meet (b) the particular demands made upon it at that moment.

The abilities of different bodies to meet the same demands vary widely. The abilities of the same body to meet the same demands differ at different times. The demands themselves are constantly changing, quantitatively and often qualitatively. Both quantitative and qualitative changes, if they occur slowly, by small degrees, permit the adjustment of the body to them, sometimes in extraordinary total degree. Conversely, large abrupt changes, either quantitative or qualitative, are correspondingly hard to meet and for this reason are the great causes of disease, specific or otherwise. But no disease can properly be said to exist, however extreme the demands may be, if the attempts at meeting those demands are successful.

Conscious efforts at the control of disease necessarily take the two forms of (a) cultivating the abilities of the body to meet changes it is likely to encounter, and (b) regulating the changes, so far as possible, to which the body is to be exposed. Success in either direction means health. The former (a) is Hygiene, and acts positively to increase the adaptability of the body to the changes; the latter (b) is Sanitation, and acts negatively to make adaptability on the part of the body unnecessary. The former is therefore the positive road towards health, the latter the negative road. Conversely, the former is the negative road toward the prevention of disease, while the latter is the positive road to this end.

The body does not develop disease to any great extent *from within itself,* unless indeed senility be considered a disease. When the body becomes diseased it is usually because of some form of invasion *from outside itself.* Given moderate surroundings, whether their moderateness be the result of natural circumstances or of artificial control, health will continue so long as the body maintains its ordinary capacities for adjustment. Disease arises chiefly, not because the body adjustments to ordinary external conditions fail, but because unusual or "abnormal" external conditions develop. It is the great function of Sanitation to prevent disease, because it is the great function of Sanitation to control surroundings—to keep quantitative changes within limits, and to prevent or minimize qualitative changes that may cause pain or damage.

To control surroundings to the point of excluding the causes of disease usually involves more than the direct control of those causes alone. Sometimes such causes are not susceptible of direct control. Almost always, the control of causes of disease must be attained through the control of subsidiary factors, and the control of these subsidiary factors of disease usually involves the control of still other factors, subsidiary in turn to them. Thus the

attempt of our castaway to secure shelter from excessive cold may necessitate a whole series of preliminary actions before he attains his end. First, he must find a sheltered spot. His search may be long, wearisome to exhaustion, perhaps even wholly unsuccessful. If he finds a good place, it may already be occupied by bear, wild-cat, snake, or insect, the driving out of which may necessitate the manufacture of some kind of weapon, which in turn may require the preceding development of tools. The almost infinitely varied arts of today have nearly all arisen from the direct requirements for mere survival, in some such sequence as above illustrated. They have developed, as man's desires and opportunities increased, from those necessary for mere survival to those contributory of comfort, ease, luxury, etc. In the consideration of Sanitation, however, only so much of the control of surroundings as bears directly on Physical Welfare can be included; otherwise a treatise on Sanitation, with its subsidiaries, would become a treatise on all human activities. In the consideration of Hygiene, the control of surroundings is not under consideration, except partially and incidentally; the main topic is the ability of the body to meet whatever surroundings may arise.

Effects of Association

So far we have learned from our castaway that Hygiene is a fundamental which consciously or unconsciously, voluntarily or involuntarily, *every living thing* employs every moment of its life; that Sanitation, conscious or unconscious, is the next essential, tending to modify conditions which otherwise would terminate life, or make it painful, restricted, undesirable. So long as our castaway lives, he cannot escape from practising and more or less correlating these two. Can he, while alone on the island, practise also Preventive Medicine, Epidemiology, Therapeutics, Public Health? It is of course true that for the

more advanced forms of the first three, as for the more advanced forms of Sanitation, he will not have the necessary facilities, in the absence of laboratory, hospital, instruments, drugs, chemicals, apparatus, trained assistants, etc., even if he should have the necessary knowledge and expertness. But we may trace some crude foreshadowings of Preventive Medicine in such efforts as he may make to escape infestation by wood-ticks or lice through cutting his hair; to escape the effects of a suspected poison he may have swallowed by inducing vomiting; to escape the worst effects of a wolf-bite by cauterizing the wound with fire. Similarly, the destruction of poisonous insects or reptiles, poisonous plants or dangerous animals that may surround him is an embryonal form of applied Epidemiology. Against the more specific diseases of mankind, however, he will find little need to guard, for the absence of human associates, so handicapping to his Sanitation in some respects, insures an absence of very many such diseases, since the germs which cause them flourish as a rule only in the human body; and, except as he may have brought some of them with him to the island in his own body, he will not while alone encounter many dangers of this sort. As to Therapeutics, if he becomes sick he may at least use the fundamental treatment, rest; and for cuts and fractures, he may devise some sort of care. But Public Health he can by no means practise, even in crudest form, for Public Health involves inter-relations with other humans, and such inter-relations cannot exist in a population of one. Health and Physical Welfare he may seek and find but he will attain them if at all by other paths than those of Public Health.

Public Health

Imagine now his solitude invaded by a group of strangers. He will of course see their advent with much anxiety, lest they should murder, enslave, or rob him. But

if they prove to be as friendly and well-intentioned towards him as he could wish, they nevertheless introduce new factors into both his Hygiene and his Sanitation. The changes may be slight but also they may be very extensive, depending quantitatively on the degree of intimacy he may have with them, and qualitatively on the kind of people they are. For instance, the available foodstuffs of the island, quite sufficient for our castaway alone, or the drinking water, or the fuel, may not now be enough to go round. On the other hand, the invaders may bring with them knowledge, tools, supplies, which far offset the increased number of mouths to be fed. He may have been placing his discharges in a stream which they now wish to use further down as a water supply; or they may settle upstream from him, and their discharges may pollute his water. If he brought some disease germ with him, which was harmless to him as an immune "carrier" (see Immunity) he may nevertheless now transmit it to them with disastrous results; or they may have brought with them syphilis, typhoid fever, etc., which he may contract from them and to which he may succumb. Should there be yellow fever or malaria amongst them, the mosquitoes of the island, heretofore harmless though irritating, may by biting the infected persons, become transmitters of these diseases. In short, just as it was quite impossible for our castaway to practise Public Health while alone, so it is now quite impossible for him to avoid practising it in some form, however crude; while the future success of the little colony necessarily will depend upon how successfully it is practised. Hygiene is for the individual. Sanitation for his surroundings; but for groups of people, Public Health is essential.

Summary

Certain terms, related to each other and often confused, are Physical Welfare, Health, Hygiene, Sanitation, Pre-

ventive Medicine, Epidemiology, Therapeutics, and Public Health. Disease, as a condition converse to Health, must also be considered.

Physical Welfare is the desired end of all the efforts indicated by the other terms, and includes two factors, bodies operating successfully, and satisfactory surrounding conditions.

Health includes only the first of these, *i.e.,* bodies operating successfully; it does not imply that the surrounding conditions are satisfactory.

Hygiene deals with the body, its operation, and especially its adjustments to its surroundings and to the changes in them.

Sanitation deals with the surroundings, their control, and especially the adjustment of the surroundings and of the changes in them essential to the body. Such changes may be quantitative, involving only an increase or a decrease in the usual factors in constant operation, such as variations in temperature; or they may be qualitative, involving entirely new or unusual factors, rarely encountered, such as poisons. Only those surroundings, and only those changes in the surroundings which enter directly into Physical Welfare are considered here.

Preventive Medicine is a highly technical division of Hygiene concerned with developing in the body special more or less artificial methods of adjustment to causes of disease. Such is the use of quinin in advance of infection with the malarial parasite, to ward off its effects, if it should be encountered.

Epidemiology is a highly technical division of Sanitation, concerned with eliminating or minimizing the causes of disease in the surroundings, to the end that adjustments to them, natural or artificial, need not be developed. Such is the destruction of the malaria mosquito.

It is evident that Hygiene, as distinguished from Preventive Medicine, and Sanitation, as distinguished from

Epidemiology, deal with quantitative adjustments; both Preventive Medicine and Epidemiology deal with qualitative adjustments. Hygiene is concerned chiefly with the direct promotion of Health, by keeping the body adjustments adequate; while Sanitation is concerned chiefly with the prevention of disease, by keeping the demands of the surroundings within bounds.

Hygiene and Sanitation are thus correlatives but quite distinct. In studying Hygiene we take certain surroundings as given and then consider the reactions of the body to them in detail. In studying Sanitation we take the ability of the body to adjust itself as given, and then consider the surroundings and their effects upon the body in detail.

Disease arises when a painful or damaging adjustment or attempt at adjustment is made. Such unsatisfactory adjustments may result from a *quantitative* failure on the part of the body to meet a quite ordinary demand of the surroundings; from an excessive *quantitative* demand of the surroundings, made upon a body of ordinary powers; or from any like *quantitative* excess of demand for adjustment over supply of adjusting ability. They may arise also from *qualitative* discrepancies between the demands of the surroundings and the adjusting abilities of the body.

Therapeutics, concerned with the care of the diseased, deals with all measures designed to restore the adjustments to the point where they are no longer painful or damaging, either by increasing or creating an ability of the body to adjust; or by reducing or removing the demand of the surroundings for adjustment. The further restoration of a damaged body to Health is a field in which Therapeutics, Hygiene, and Sanitation all coöperate.

Public Health is the summation and application of all the means of Physical Welfare to groups of people rather than to individuals, and considers the demands of their

inter-relations with one another as well as the demands of each individual by himself.

PROJECTS FOR CHAPTERS I AND II

1. Devise for use in the class room a scheme similar to an organization chart that will show the relation of Hygiene to other branches of Physical Welfare.

2. Prepare for presentation to the class a comprehensive report describing the Federal Public Health Service. Procure slides to illustrate your report. Show the relation of this service to Hygiene, to Sanitation.

3. Make a thorough study of the purpose, organization, and work of the local Board of Health, and report your findings to the class. Discuss the value of the work of this Board. Divide the activities of the Board into groups—Hygiene, Sanitation; Preventive Medicine, Epidemiology; Therapeutics.

4. Prepare a review of the History of Public Health Nursing and point out the phases of Physical Welfare involved.

5. Spend one day with a public Health Nurse in your city or county to get first-hand information about her work. Determine what preparation is necessary to carry on the work successfully and report your day's experience to the class. Include in your report a discussion of the value of the Public Health Nurse's service. Classify on same basis as in No. 3.

6. Prepare a pamphlet on Hygiene in the prevention of tuberculosis that would be of value to patients with the disease.

7. Prepare a pamphlet on Sanitation for the prevention of tuberculosis.

8. Prepare illustrations for the pamphlets described in Nos. 6 and 7.

9. Report on the work of Von Behring for the prevention and cure of diphtheria by the use of antitoxin. Discuss the economic value of his contribution. Discuss the relationship of his work to Hygiene.

10. Report on contributions to Physical Welfare made by the following:

Walter Reed	Lord Lister
Major-General William C. Gorgas	Leonard Hill
Louis Pasteur	F. G. Banting
Robert Koch	

11. Report on the work of sanitarians in the prevention of any one of the following: malaria; yellow fever; bubonic

plague. Indicate why such work is primarily epidemiological; and why epidemiology is classed under sanitation.

12. What is the relation of vital statistics to the health progress of a nation? Support your statements by actual examples from statistical studies and health reports.

CHAPTER III

WHAT IS NUTRITION?

Our bodies are composed of materials which, when "alive," are continually occupied in *living;* from a physical standpoint this means that they are continually occupied in converting the heat of the sun into the motion, sensation, thought, electricity, and heat of the body.

Broadly speaking, every one of the chain of transformations involved, beginning with the generation of the sun's heat in the sun and ending with the output of the body in the forms of motion, sensation, thought, electricity, and heat, are directly or indirectly processes of nutrition, for they are every one essential to the formation of the body, to its maintenance in size and activity, and to the formation by the body of new bodies; that is, to reproduction.

More narrowly, nutrition is considered as dealing with the reception and use within the body of materials (foods) derived from outside the body, the chief ends for which they are used being: (a) the actual building up of the body by additions of certain materials (growth and repair), and (b) the furnishing to the body of oxidizable materials (fuel), the destruction of which through processes of oxidation (burning) forms the last link in the chain of transformations by which the heat of the sun becomes the energy and heat of the body.

Essential Processes in Food Building

Conversion of the Sun's Heat into Energy. Eight hundred and sixty-four thousand miles in diameter and

with a temperature of 6,000 degrees Centigrade, the sun, from its millions of square miles of surface, radiates incalculable heat to all the solar universe. The eight planets and the subsidiary bodies of our system if put together would form but 1/1000 part of the sun's bulk. Floating as mere dots in the great void about it, they intercept the rays that constitute the great sphere of radiant heat of which the sun is the nucleus, to the extent of only 1/120,000,000 part of the total. The rest is dissipated in space.

Of the modicum thus distributed to the planets, small as it is, our earth receives as its modest share only the 1/2000 part. This is, however, sufficient to supply about two (small) calories per square centimenter of the earth's surface when the sun is shining. About half of this is taken up by the earth's atmosphere, and much of the remainder falls upon rocks and sea rather than upon vegetation. That portion of sunlight which encounters the living green matter (chlorophyll) of grasses, shrubs, trees, and other plant life, enables the chlorophyll to build from the air and the soil various substances (carbohydrates, fats, proteins), which with water and salt form the bulk of plant bodies. These, when eaten by animals, undergo various chemical changes, through which and especially through those known as oxidation, *heat and energy* are supplied to the animal body. Some of the substances thus introduced into the body are *changed into and incorporated with* its substance, thus forming the actual living material of the animal body itself.

The Rôle of Chlorophyll. So far as we know, the sun's rays do not in and by themselves furnish the sun's energy directly to any living thing except to chlorophyll, the green matter of plants. The sunlight, which is transmitted to us through 92,000,000 miles of space and which we say "energizes us for the day's labors," does not directly either through its light or heat really furnish the animal

body directly with any new increment of power. In so far as it warms us or our immediate surroundings, it lessens the amount of body heat we should otherwise be called upon to develop, and so conserves the stored-up heat obtained from our food. But that body heat itself, as well as the energy required for the vast array of continuous body processes which develop and transform it, making it conservable or expendable, although derived from the sun is so derived only by the roundabout route through our food, above described, and not at all by merely basking in the sunlight. Chlorophyll only, of all living things, can use the sun's energy directly to make starch and fat from the carbon dioxide (CO_2) of the air and the water (H_2O) of the air and soil; to make protein, probably from starch and certain nitrogen-containing salts of the air and soil; and to make other substances, primarily of importance to the plant, but also of essential importance to the animal, since the animal can make none of these things from the crude materials themselves. Should chlorophyll disappear from the globe or cease to function, not only all green plant life, but all animal life, certainly all animal life above the very lowest microscopic forms, would disappear also by pure starvation.

Bacteria Necessary to Chlorophyll

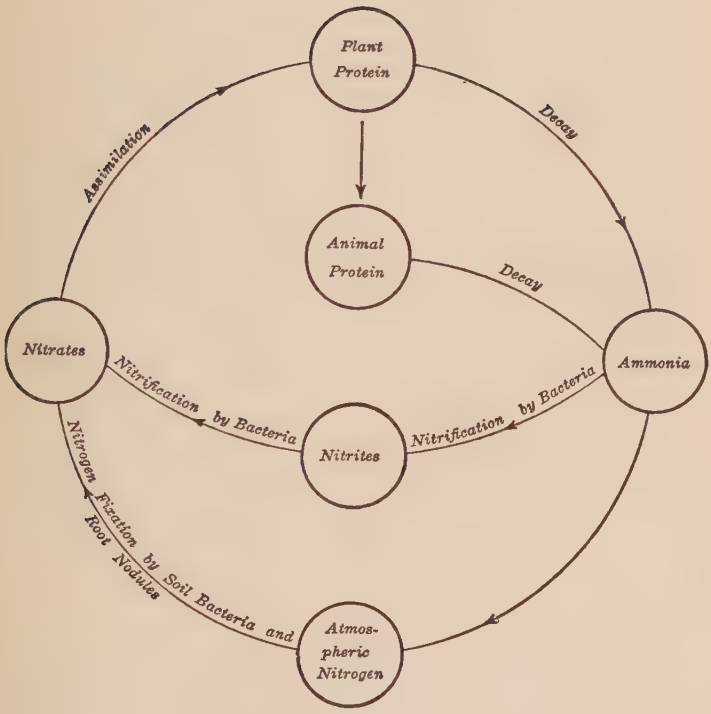
But back of the chlorophyll itself, and necessary to its formation and action on the great scale which is so familiar to us are certain bacteria. These are lowly germs of the soil, so low in the scale of life that we hardly know whether to call them plants or animals or something more or less than either; microscopic forms, which in incalculable numbers inhabit the earth's crust. They carry on in darkness the formation of those nitrogen-containing salts, without which chlorophyll, although quite equal to the task of making starch and fat, cannot make protein—cannot, since chlorophyll is protein, even reproduce itself.

Carbohydrates, Fats, Proteins

To understand nutrition from the standpoint of construction, we must first understand that the active living substance of all living things,—the substance which grows, or moves, or secretes, or feeds, or thinks—the bone (in great part), the muscle, the gland, the nerve, the brain, the skin of the animal, the active cells of the plant—is protein. Fat, starch, sugar, salts, water, are all incapable of any of these functions.

Protein differs from the fats and carbohydrates (starches and sugars), from most salts, and from water, in that it contains nitrogen as one essential chemical constituent. Water consists of hydrogen and oxygen chemically united; fats and carbohydrates consist of hydrogen, oxygen, *and carbon,* chemically united in various proportions; protein consists of hydrogen, oxygen, carbon, *and nitrogen* (together with phosphorus and sulphur) chemically united in extremely complicated and enormously variegated ways. Without nitrogen, therefore, protein cannot exist; without nitrogen, there can be no physical life, as we know it.

Since protein only, of all the substances in the world, can really physically live; since protein only can make, as it does when in the form of chlorophyll, from carbon dioxide and water, the starches and fats which act as body fuels for itself and for other living things; since protein only can make, as it does when in the form of chlorophyll, itself and other proteins, without protein there can be no physical life. To say this is also to say that without nitrogen there can be no physical life, for without nitrogen there can be no protein. Even oxygen is not more essential. Chlorophyll, itself a protein, cannot exist or act unless nitrogen is available to it—although once so supplied it can manufacture food for almost all creation. But even


Plant Protein
Decay
Assimilation
Animal Protein
Decay
Nitrates
Ammonia
Nitrification by Bacteria
Nitrification by Bacteria
Nitrites
Nitrogen Fixation by Soil Bacteria and Root Nodules
Atmospheric Nitrogen

chlorophyll, capable as it is of using the simple compounds, carbon dioxide and water, fails when it comes to using the pure elements, hydrogen and nitrogen. The immense reservoirs of nitrogen all about us in the atmosphere are not available to chlorophyll in that elemental form. Only the bacteria previously mentioned can use nitrogen as nitrogen—nitrogen as it is in the air—and only these bacteria can build it up into compounds available to chlorophyll. Hence physical life as we know it on this planet depends in its present volume and character upon bacteria—indeed, on a few but very widespread species of these lowly organisms.

Chlorophyll then is the factory; sunlight is the power used in the factory; carbon dioxide, water, nitrogen salts, and other simple substances are the raw materials; carbohydrates, fats, and proteins are the products, oxygen is a by-product.

Only the protein of the chlorophyll can make starches, fats and its own proteins. Of all substances in the world, only protein can truly live, physically.

Nitrogen is an essential constituent of protein, and only certain bacteria of the soil can build up nitrogen into compounds available to chlorophyll.

Circulation of the Elements

This planet, so far as we know it, consists of about ninety different substances which we call elements, the various combinations of which make up all the material things with which we are acquainted.

The sum total weight of all the material things in the world—that is of all the elements in the world—is practically constant. The weight of the world as a whole loses little and gains little even in the course of eons. As a matter of fact, only that exceedingly thin skin of the planet which we call its crust, together with the atmosphere, is

exposed to the outer universe. All under the crust is shut away from gain or loss in weight completely. Hence the only sources of the material which can be used to build up anything else in this world, including plant bodies and animal bodies, are the exceedingly thin crust of the earth and the air. What we call a new-growing plant or a new-born animal is but a re-combination of old material which has been combining and re-combining and breaking down from combination, for eons past, ever since the world began. Of the ninety elements some fifteen or sixteen enter into the composition of living things. The rest are, so far as concerns the body, inert or poisonous. This restricted group,* of which carbon, hydrogen, oxygen and nitrogen form the preponderating mass by weight, have moved up from their elemental forms into plants, have been eaten in that form by animals and have returned to the soil or the air on the death of the animals, many times before the animals or

* The Elemental composition of the human body according to Sherman is as follows:

Oxygen	65	per cent
Carbon	18	per cent
Hydrogen	10	per cent
Nitrogen	3	per cent
Calcium	2	per cent
Phosphorus	1	per cent
Potassium	0.35	per cent
Sulphur	0.25	per cent
Sodium	0.15	per cent
Chlorine	0.15	per cent
Magnesium	0.05	per cent
Iron	0.004	per cent

Iodine
Fluorine .....very minute quantities
Silicon

Fats and carbohydrates, the energy-producing food, contain carbon, hydrogen and oxygen. Proteins, the tissue builder, contain the above and nitrogen in addition, with phosphorus and sulphur. The other elements, that enter into the composition of the human body, are needed in small amounts and will usually be provided if the three food principles mentioned above are well proportioned.

plants of the present generations became composed of them; and they will inevitably be inherited from their present tenants by succeeding generations, as time goes on.

Nutrition of the Infant

The body of the new-born infant is therefore necessarily composed of material as old as the material of the oldest rocks; it exists in old forms of combinations of these old materials, but newly made and of the greatest intricacy.

These combinations fall into the groups already mentioned, proteins, fats, carboydrates, salts, water, having the same general compositions and functions as in any other animal body.

True, we have very definite proof that the proteins of different species of animals differ in ways which we cannot express chemically as yet; also that the different fats occur in different proportions in different animals; and we are at liberty to guess that carbohydrates, salts, and water may vary somewhat in their exact combinations, as we know they do in their proportions. Moreover, we have every reason to believe that as the outward forms of different individuals of the same species vary in minor ways, so also do the combinations of elements in their bodies vary slightly from individual to individual. Indeed, we have fairly good proofs of this in the varying coloration of such individuals, in the variability of their different resistances to different poisons, in their varying ability to become immune to certain bacterial and other poisons, and in other ways. Nevertheless, in general, the close similarity of one individual of a species to another is marked. The baby's protein is composed, like that of its parents, of carbon, hydrogen, oxygen, nitrogen, phosphorus, and sulphur in proportions and combinations chemically indistinguishable from those of its parents; and its other components are likewise similar to those of its parent.

When the baby begins life as a fertilized cell in its mother's uterus, it weighs practically nothing; at birth it weighs, say nine pounds. All this material was accumulated and combined in the mother's uterus, being abstracted from her blood in the form of proteins (or rather their digestion derivatives), fats, carbohydrates, salts, water, as they circulated in her blood for the nourishment of her own body.

She obtained them from her food, from plants or animals which she had eaten, digested, and absorbed for her own needs. Her food necessarily consisted therefore of the proteins, fats, carbohydrates, salts, and water of those plants or animals or both, together doubtless with some additional water taken as beverage, and of salt, at least of ordinary table salt (NaCl) taken as a condiment or flavor. Such animal food as she eats owes its own formation to the animal, which in turn has fed on plants; so that the chain is complete from the soil and air to the newborn babe. It uses exactly the same things in the same forms for its growing body that the mother uses in her own, and derives them from her blood exactly as her own body cells derive them. The two blood streams are distinct, but the substances they require pass from one system to the other through the blood vessel walls by osmosis, the waste product of the child passing in reverse direction.

The Infant After Birth. When the baby is born it abruptly ceases to derive from the mother's blood its necessary protein, fat, carbohydrate, and other nourishment. These needs through the remainder of its life must be supplied otherwise. No longer will it receive into its blood stream food predigested by its mother and requiring only to be assimilated; it must now take by mouth undigested food, and digest, absorb, and assimilate it on its own account.

The baby on the day of its entrance into the world would at once be confronted by all the problems of nutrition re-

lating to the selection, proportions, amounts, and preparations of foodstuffs, were it not that these problems have been solved for the baby by the existence of mother's milk. True, the proteins and other components of the mother's milk are not the same as those which she has so far supplied to the unborn child through her blood in the form of foodstuffs she herself uses. They are products from those foodstuffs, products manufactured by the mother herself in her own breasts. They are no longer predigested, but must be digested by the baby; nevertheless, experience proves that the mother's milk is far better adapted to the infant's needs than is any other food yet devised.

Failing the milk of the mother herself, the milk of another human mother is by far the next best substitute. Failing human milk, the milk of other animals, notably of the cow or goat, may be used but it is on the average much less satisfactory. That "milk is milk" is no more true than that "coal is coal." The furnace adapted to anthracite may be induced to burn soft coal but at a cost in attention, labor, breakdowns, and unsatisfactory results that is ruinous. Just so with milk. The human body furnace is adapted to "burn" human milk; conversely, human milk is adapted to be burned in the human body furnace. Any substitute for human milk, while likely to be better than nothing, is none the less a substitute and the baby is likely to have much trouble in adjusting himself to it.

Adjusting to "Adult" Foods

As age increases, the body, having a great capacity for adjustment to changing conditions, will, if it has the chance to learn such adjustments by encountering different foods, gradually become able to digest, absorb, and use a wide variety of proteins, fats, and carbohydrates. Such opportunities for adjustment should be afforded from the

sixth month onwards, whether human milk be available or not. The usual rules for cultivating adjustment should be followed as outlined in a previous chapter.

But the body after infancy no longer finds any one "perfect food," such as was afforded by mother's milk. Judgment and knowledge must take the place of automatic acceptance. The proper foodstuffs must be carefully selected, combined in the proper proportions, used in the proper amounts, prepared well, and as a rule served in acceptable ways, if the child and adult are to be satisfactorily nourished under modern conditions. It is not improbable that an abundant supply of the ordinary foods would require little adjustment for active outdoor people, eating with excellent appetites, and having constantly a great deal of strenuous and varied exercise. Soldiers and lumbermen do not demand the same kinds of care in feeding as sedentary people. Certain fundamentals, however, must in general be observed, consciously or unconsciously —otherwise disaster more or less profound is likely to ensue. Undoubtedly, appetite, cravings which develop under unsatisfactory food conditions, and the mere desire for change of diet are in themselves automatic safeguards against unsuitable diets, resulting in casual experiments which by the trial and error method may lead to more or less satisfactory dietaries. By such rule-of-thumb methods, and under the pressure of driving necessity, mankind primarily solved the problems of nutrition sufficiently well to survive long before the study of nutrition was at all developed. True, mistakes of huge proportions, with tremendous damage, have been made (see pellagra, and scurvy).

But it is only fair to acknowledge that these mistakes have been less the deliberate selection of an improper diet, based upon poor judgment, than the gradual development of a poor dietary, forced by economic conditions,

Malnutrition

The comparatively recent findings that about one-fourth to one-third of the general school population of North America, despite fairly good food supplies, are *underweight for height and age* has attracted very much attention to "starvation in the midst of abundance" going on in this important element of the population. The causes here operating are: ignorance of the situation; the assumption on the part of the parents that because a good dietary is afforded, it will be eaten in proper amounts and proportions; the substitution of carbohydrates (fuel foods), especially sugars, for proteins (growth foods) at the very period of life when growth is the main physical business of the body; and in some cases actual disease or defect, particularly such as diseased tonsils and adenoids.

On the other hand, malnutrition of the converse character, *over-weight for height and age,* occurs also amongst school children to some extent, but even more amongst the older adults. Although less studied to date than the first described, the adult over-weight situation would appear to be due to ignorance; the assumption that because a rich dietary can be afforded it should be eaten, regardless of amounts and proportions; the substitution of proteins for carbohydrates at a period of life when growth foods are much less required than fuel foods; excesses even in the carbohydrates, combined with lack of exercise and therefore with lessened activity of respiration; finally, the belief that weight "naturally" increases with age. It seems not unlikely that the proper weight for height at the age of thirty is the proper weight for height thereafter, and *that watching the weight for height at all ages is the safest single guide to successful nutrition, so far discovered.*

Results of Nutritional Adjustment

The hygienist of today would meet present nutritional needs by the substitution of the more exact knowledge we have now concerning every phase of nutrition for the rule-of-thumb methods heretofore the only kind available. Similar substitutions in other arts have revolutionized them. The success of scientific feeding amongst domestic animals and human babies, whose diets are completely controllable, can hardly be repeated in full amongst the older persons, because it can hardly be expected that such dieting will ever be as completely carried out. But great improvements can be made through education and through changes in the food habits of the population by propaganda. Such improvements will result in more physical ease and efficiency, less languor and strain, the prolongation of youth, the accumulation and the expenditure of more human energy, and the lessening of the nutritional diseases.

We cannot hope, however, through good nutrition, to abolish the diseases dependent on infection by germs—bacteria or protozoa—for the general experience of mankind is that these diseases attack the well-nourished as well as the poorly nourished. Moreover, stock feeding experiments amongst the lower animals, wonderfully successful from the nutritional standpoint, have completely failed as a weapon against infection. There are, however, a vast number of disabilities, defects, distresses, and inefficiencies, due to malnutrition, quite outside the field of infection, as well as certain definite nutritional diseases. *To replace these by bodily well-being, good physical development, physical happiness, efficiency and alertness is the great aim of modern researches into foods and feeding.* Incidentally, the truly nutritional diseases will be thus largely prevented—but not the infections.

Summary

Nutrition, although ordinarily considered as chiefly related to foods and feeding, really involves every operation of the body, since all such operations are concerned in it and dependent upon it.

Broadly considered, human nutrition is the transformation of the sun's energy into human activity, and is therefore THE fundamental study of all biology.

The initial transformation of the sun's energy into forms available for body use is performed by the chlorophyll of plants, and results in the formation of various chemical compounds (starches, fats, proteins, etc.), which in the form of foods can be transferred with their stored energy to the body, and be there broken down. Not only do these compounds (a) furnish energy, but also they (b) enter into the composition of the body, maintaining or increasing its actual physical bulk and structure; and thus (a) act as fuel; and (b) furnish building material.

Chlorophyll itself is dependent for its own existence, and for its ability to manufacture other proteins, which are the chief building foods of all living animals, upon supplies of nitrogen-containing salts, which in the quantities required can be adequately provided only by certain bacteria, which prepare the salts from the free nitrogen of the air.

Animals are not only unable, like chlorophyll, to use the elements in elementary form for food, but, unlike chlorophyll, cannot use the simpler compounds of the elements either. In fact, only the elaborate and complicated chemical compounds formed by the plant or obtained, after modification, from other animals, can be used by animals for fuel or for building purposes. Thus animal life on this planet is wholly dependent on plant life, which in turn is dependent on bacterial life.

Thus it comes about that the materials at present existing in the form of animal or plant bodies is material which has existed in similar forms in preceding animals and plants, for eons—its existence in living forms alternating with its existence as constituents of the soil or atmosphere or waters of the globe.

The nutrition of the infant before birth is accomplished by sharing in the foodstuffs of the mother, as they circulate, after digestion and absorption by her, in her blood vessels, for the nourishment of her own body. Proteins, fats, carbohydrates, etc., thus reach the developing embryo, predigested and ready for assimilation.

The nutrition of the new-born baby depends upon the ability of the baby itself to digest proteins, fats, carbohydrates, etc., presented to it in undigested forms. The problems concerning the kinds of these foods which should be presented to the baby, the proportions, amounts, etc., are all solved by the mother's milk, which contains proteins, fats, carbohydrates, etc., elaborated from the same foodstuffs, taken in her food.

The adjusting of the new-born infant to a larger and larger variety of food is accomplished, like any other adjustment, by imposing it upon him, and thus eliciting his adjusting abilities. Like other adjustments, these should be made gradually, with intervals of rest.

Malnutrition throughout life may be measured, at least so far as quantitative excess or lack is concerned, by noting the relation between weight and height *for age*. Definite departure of an individual from the average for his race should attract attention and be investigated. Malnutrition is one effect of a number of diseases, and the presence or absence of these as causes of malnutrition must be determined first. On the other hand, some forms of malnutrition result in definite diseases, having their own identity, and susceptible to treatment through dietary changes.

The malnutrition of school children tends to be of the underweight variety, and is generally due to over-exercise, lack of sufficient rest, too much fuel food (carbohydrate), and insufficient building food (protein).

The malnutrition of adults, especially of those at or above middle age, tends to be of the over-weight variety, and is generally due to lack of exercise, and too much food, of both kinds, perhaps especially of proteins.

Through intelligent study of foods and feeding, through the education of a few and through propaganda to the many, the general principles of nutrition may be incorporated in the food habits of modern peoples to their great advantage in physical well-being and efficiency.

CHAPTER IV

SOURCES OF FOOD PRINCIPLES

Value of Mixed Diet. In selecting gasoline for an automobile the prime consideration is, which grade will give the maximum of energy at a minimum cost per mile; but in buying food for the human engine, we must consider repair, and in young people growth, as well as energy production. *The greatest amount of energy at the lowest cost is not a safe guide to food values.* A pound of fat will yield energy enough to supply the needs of a very active adult for a period of twenty-four hours; two and a quarter pounds of sugar will do the same; yet every one would at once reject either of these diets as a continuous performance. Moreover, both fats and carbohydrates lack the nitrogen which is essential to building up proteins, and therefore, although they may supply the fuel requirements completely, they ultimately fail as a complete diet because they cannot repair the ordinary protein waste of the body, much less produce the new protein required for growth.

Protein, on the other hand, furnishes both nitrogenous and carbohydrate moieties; it therefore serves both for fuel and building, so that it is possible to subsist on protein without fat or carbohydrates; but *it is impossible to subsist on fat or on carbohydrate or on both, without protein.* The untamed Eskimos, living all but exclusively upon meat and fish, approximate very closely a pure protein diet, diluted with fats but almost lacking carbohydrates. Experience and investigation both show, however, that a

mixed diet, containing protein, fat, and carbohydrate, as well as the salts and water which cannot well be omitted from any dietary list, is the most satisfactory in the long run. These may be obtained from many different sources and may vary in quality. They may be had already combined in different natural food products, or they may be had in pure form, especially the starches, sugars, and fats, which may be combined at will in any given proportion.

The experience of the human family over thousands of years has shown that almost all animal bodies furnish good food for man, whether the animal be mammal, bird, fish, reptile, snail, lobster, oyster, clam, or even man himself; and that on the other hand, the range of plant life suitable to man is but a fraction of the total vegetable forms. Cellulose, the woody parts of plants, man cannot use for food at all, and he is thus shut off from a large part of the vegetable world as a direct source of food supply.

From the organic or mineral world, water and a small number of salts are available in plant and animal food and in a more or less pure form in nature and artificial preparations. Salts and water are not foods in the usual sense, and their intricate and intimate functions in the body are but partly understood and hitherto have been rather neglected by students. Some of their uses in the body are obvious but it is probable that they have other uses hardly more than suspected at present, the future demonstration of which may give us new methods of body-function control.

Sources of Protein

Since actively living parts of all living things are essentially protein, all animal and vegetable foods furnish protein. But the animal body furnishes pound for pound more protein than does the plant body. This is easily understood, for the activities of plants, important as they are,

lean chiefly to construction, not to motion, secretion, sensation, and other vigorous energy-consuming functions of the body.

Plant Protein. Plants are the storers of energy, the producers of complicated chemical bodies from simple ones, the furnishers of high-power nutritional explosives, the manufacturers of nutritional "gasoline." Not only does plant protein form a relatively small proportion of the total bulk of the plant, but in various respects it also differs in character from animal protein, many of the plant proteins yielding on analysis a chemical structure different from that of the animal proteins. It is true that these differences are not so great as to entirely impair the use of plant proteins as food, but they are sufficient to prevent plant proteins from furnishing the materials needed to build animal proteins so readily and completely as do the animal proteins themselves.

Animal Protein. Animals, in contrast with plants, are the consumers of the stored energy which plants accumulate; they are the breakers-down of the complicated chemical bodies which plants put together, the "big guns" which discharge the "high explosives," the automobiles which burn the gasoline. Animals cannot make their own proteins from carbon dioxide, water and nitrogen-containing salts, as plants can. Animals must obtain ready-made proteins as the basis for making their own. They may obtain them from plants or from other animals. When a plant-eating animal has obtained the plant proteins and made them over into its own proteins, animal-eating animals, including man, find these made-over proteins more valuable to them as food, nearer in chemical structure to their own, more complete and therefore more certain to fit their needs, than were the original plant proteins.

This discovery, that protein from animal sources ranks much higher as a human foodstuff than does protein from

vegetable sources is one of the definite advances of the last few years. It is not long since all proteins, whether vegetable or animal in origin, were thought to rank equally and to be entirely interchangeable in human diets. It was on account of high protein content that beans were at one time spoken of as the "poor man's meat"; but the detection of the low quality of bean protein denies them a real right to such a title. Vegetable proteins also differ from each other in relative values and are not themselves interchangeable weight for weight in human (or animal) diets.

We must conclude then that while we can and do secure much valuable protein from vegetable sources, our chief and best supply is the animal body itself or its derivatives, such as milk and eggs; and that while it may be possible to sustain human life on a purely plant diet, in practice even strict vegetarians find it well to use eggs, milk, and milk products to supply the lacking protein.

Sources of Fats and Carbohydrates

Fats and Oils. As almost all animal bodies supply proteins suitable for human use, so also almost all animal bodies supply fats and oils suitable for human use; but plant bodies, little as they supply protein, supply fats and oils to an even smaller extent. A very few plant species supply all the vegetable oils that we use as food. Most of our ordinary table vegetables contain little or none. Mineral oils are used in medicine, but despite their high heat value they have no nutritive value because the body cannot absorb them nor break them down. Their chemical constitution is radically different from that of animal or vegetable oils.

Carbohydrates. Carbohydrates (starches, sugars and their close allies) are found in the animal body in the form of glycogen (animal starch), chiefly in the muscles and liver, and as glucose (a form of sugar) widely dis-

tributed throughout the body. However, the amount of carbohydrates found in the animal body is so insignificant that it is seldom referred to at all in dietary lists.

The great source of carbohydrates is the plant body. They are manufactured by plants from the carbon dioxide and water of the air and soil, and by certain plants they are stored in large quantities in roots (carrots, turnips), tubers (potatoes, artichokes), seeds (wheat), fruits (pears, apples, various berries), leaves (onions), to be used by the plants for their own purposes, or for offshoots and seedlings. Sugars are derived from starches by the physico-chemical process of hydrolysis which takes place in the plant, in the human body, and in the test tube under certain conditions. One function of the saliva is to transform the starch of the food into sugar.

Sources of Salts and Water

Both salts and water enter into the structure of plants and animals, and therefore a diet of plants or animal food contains them. Animal food is not a great source of salts, unless the bones are used; vegetables, particularly leaves, have a higher content of these minerals. Water forms about sixty per cent of the bulk of most fresh meats, and from seventy to eighty per cent of most fresh vegetables, so that an appreciable amount of water is derived from both. But the quantities of water so obtained by the human consumer are as a rule quite insufficient to meet his demands, so the greater part of his supply comes from the beverage use of pure water or of water variously disguised and flavored, as tea, coffee, beer.

Nature and Sources of Certain Accessories

There are certain other substances which, though in no sense foods, are present in most foods and have more or

less important relationships to the proper digestion and assimiliation of food, thereby indirectly aiding successful nutrition. These are *condiments* or *flavors* which stimulate digestion; and *vitamins,* which in some as yet little understood way, promote assimilation.

Proteins, fats, carbohydrates, salts, and water are properly called foods, for they all enter into the structure of the body in some form or to some degree, while the first three also act as fuel. It is true that only protein truly lives, so far as we know, the others acting chiefly as agents or assistants or tools or fuels for the living protein, but it is likely that water and perhaps salts actually become, for a time at least, constituents of the protein molecule.

Flavors and Condiments. Flavors include certain tastes natural to or developed in the foods themselves, and certain substances added artificially to make a naturally flavorless food more palatable. Condiments are of the artificially added group and are usually pungent or aromatic or both, rather than sweet or bland. Some of these substances by direct action on the secreting glands which prepare the digestive juices, stimulate their activity. Others act indirectly through psychic impressions. The odors of foods, when appetizing, act thus psychically also.

Vitamins. Vitamins are as yet hypothetical substances only; no single substance has yet been isolated which shows the peculiar properties which we ascribe to vitamins. We cannot, for instance, say of any one substance, "This is a vitamin," as we can say of lard, "This is a fat." Our evidence of their existence is neither physical nor chemical, nor is it obtained through sight or smell or sound or feel or taste. It is deduced from a series of observations on foods and on diseases attributed to food defects, indicating that certain perfectly good foods, unimpeachable so far as physical and chemical composition, proportions, amounts, preparation for the table, flavor, and

other items may go, yet at times fail to nourish properly; that their continued use may result in quite definite and often fatal diseases; and that the addition to such dietaries of quite insignificant quantities of certain other foods, too small to have any direct nourishing value of their own, may clear up the situation completely, securing excellent nourishing effects from the very foods which had before previously failed, and curing or preventing the diseases due to their failure.

The power to produce these effects is widely but unevenly distributed in nearly all foods of animal or vegetable origin, but it is particularly prominent in the latter. It is ascribed to *minute quantities of unknown substances,* the presence or absence of which in a given food at a given time depends less on the nature of the food than upon its individual history. If of plant origin, the points of importance are the soil in which it grew, the part of the plant which it forms, its age, the processes of refining or preservation it may have undergone, the degree of heat to which it has been subjected, and perhaps other features of its experience; if of animal origin, the nutritive history of the plants or animals on which it has lived, the part of the animal which it forms, and the processes, including heat, to which it has been subjected—all of which are quite analogous to the controlling features in the case of plants. From a study of these complicated and inter-related features, the vitamin hypothesis has been built up as the most plausible explanation of the facts so far discovered. We may therefore accept for the time being the probability that there exist three of these vitamins, derived from the soil by plants, transmitted directly to animals which eat those plants, and indirectly to animals which may eat those animals which have eaten those plants. Animals, unable to derive proteins, fats, or carbohydrates except from plants, are also unable to derive vitamins from inorganic sources, or to manufacture them for themselves; they

therefore possess them only at second hand and, as compared with plants, in smaller proportions as a rule.

The parts of plants and animals which are most rich in vitamins are in general those which have to do with the most active processes in the body economy, such as the leaves of plants, the glands of animals. The age of the plant or animal at which vitamins are most likely to be found in greatest abundance is likewise connected with the organism's own activity; hence youth shows them more abundantly than senility. To methods of refining, preserving, and storing, the different vitamins react differently, and the same vitamin in different foods may react differently to the same process.

The main deduction of practical interest is that no matter how satisfactory from a heat-supplying and body-building standpoint a dietary may be in respect to the proportion and amount of its constituents, it should also include some leaves of young plants, glands of young animals, eggs, fresh fruits, milk products from pasture-fed cows, or similar vitamin carriers; and that these or some of them should be raw and unaltered by refining processes.

Classification of Food Principles	*Chief Sources*
Proteins	Meat, fish, eggs, milk, grains, vegetables.
Carbohydrates	Sugar cane, sugar beets, fruits, vegetables, grains.
Fats	Milk, milk products, meat, fish, nuts. certain seeds.
Minerals	Fruits, vegetable, bones.
Water	Plant and animal foods, beverages.
Vitamins	Leaves of young plants, glands of young animals, eggs, milk, fresh fruits.
Condiments	Natural flavors of meat, vegetables; spices.

Roughage

Early man, like many savages today, ate obtainable plant and animal food raw or very slightly cooked, without taking any great pains to rid it of its less digestible parts or even to free it of the extraneous earthy particles or ashes it may have gathered in the vicissitudes of collection or cooking. The strenuous individualistic life of early days when each one had to do for himself everything that was done at all, permitted little attention to non-essentials; also, facilities were few and the arts of food refinement were undeveloped or unknown. But with specialism and the competition in trade of those who specialized as producers and sellers of food to their neighbors, attention to the preparation of food for marketing became a feature of successful selling, especially when food was abundant and the sellers of food numerous. A vast development of refining methods, notably in the last few decades, arose from such trade pressure; each vendor sought to distinguish his products from those of his competitors, if only by insignificant differences, so long as these appealed to his buyers.

Food Waste. The dirt theory of disease in the nineteenth century, the growing æstheticism of the popular doctrines of the day, the enormous advances in machinery and in facilities for transportation and distribution, all contributed to spread widely the demand for food products advertised as exquisitely pure, sanitarily prepared, daintily put up. All of these were good points, but their values were exaggerated to the point of faddism. The demand for white flour, for instance, resulted in refinements including bleaching of the flour, which deprived it of its most valuable constituents other than calorific. The "waste" thus discarded contained the substances which prevent the disease *beri-beri*, or conversely, the flour thus

prepared lacked the vitamin against beri-beri. The "waste" contained also most of the salts of the grain, the value of which, not recognized in an earlier day, is now known to be very considerable. More utilitarian and based on the desire to have the flour as nearly imperishable as possible for shipment and storage, was the removal of the germ of the grain, the color of which was also objectionable to the white flour æsthetes. The result of all these refinements was to weaken "the staff of life" to the status of the proverbial broken reed, the traditional belief in it remaining after its virtues had largely departed.

Disuse of Teeth. Grit in food, sand, ashes, broken bone, is intolerable to the modern mouth, tongue, teeth; yet if we reflect on the fine condition of the teeth of early man—worn almost to the gums, it is true, in the older adults, but otherwise sound—we may wonder if the soft, gritless foods of today may not be responsible for our degenerate teeth. It has been suggested that the enormous pressure which the teeth bring against each other due to the exceptionally advantageous leverage which the jaw muscles possess because of their attachments and insertions, permits great injury to any tooth which may grow slightly longer than its fellows. The wearing down of all such projections by rough, tough, and especially gritty foods would rather obviously tend to prevent the development of unevenly distributed pressures. Whether this be true or not, civilized man cannot boast of teeth at all comparable in soundness, symmetry, or strength, with those of animals or even of savages. Infection spread by mouth-spray and other interchanges of mouth discharges practically inseparable from extended social intercourse must be in part responsible; but when we notice the weakness and deformity of the modern civilized foot in comparison with the savage foot, it is not hard to imagine that the similar partial and relative disuse of modern teeth in

comparison with ancient or savage teeth, may have a similar ending.

These are perhaps academic points, worth little from a practical standpoint except as they may emphasize to the student the necessity of that phase or view of hygiene which seeks to relate definitely every adjustment which the body is called upon to make to some real bodily need or advantage; the serious upsets of the body which may be entailed in some directions by apparent improvements in others; and the constant painstaking, unprejudiced scrutiny and criticism to which a thing should be subjected before accepting it as hygienic or sanitary merely because some one has had the temerity to label it so.

Summary

The fundamental requirement of food is that it shall contain the sun's energy stored in forms available to the body, for without this *calorific value* the food cannot convey to the body the sun's energy, without which the body must cease to function, that is, it must perish, since the sun's energy is unavailable to the body in any other known way. But this is by no means the only function of food, since *repair* and *growth* are dependent on the actual addition to the body of certain food-constituents which become and form the body substance itself.

Since protein supplies both fuel and building material suited to the body, it might at first sight appear to be the all sufficient foodstuff, and it is true that life can be maintained on protein alone, and with success on protein combined with fat.

But general experience, despite the many *pros* and *cons* involved, seems to indicate that for modern man living under the conditions imposed by modern life, the most favorable diets are those containing all the three chief foodstuffs, *protein, fat,* and *carbohydrate;* with of course

the addition of *salts and water,* which is almost inevitable from the nature of our food materials as they come to us, and with *flavors* and *condiments* to encourage appetite and promote digestion. Within the last decade of years it has been shown that this list does not fully cover the items necessary, but that hypothetical substances known as *vitamins* probably exist, whose function is to make the foods assimilable in some unknown way. It is therefore obviously essential that every dietary should contain sufficient vitamins. Since they have not yet been identified, the only practical method to ensure their presence is to add to the dietary some of the food materials which research has shown contains them.

In the search for sources of foods rich in proteins, fats, carbohydrates, salts and vitamins (water and condiments being derived chiefly from non-food sources), we find the animal kingdom to be the most abundant source of the most suitable proteins, the vegetable kingdom to be almost the only source of suitable carbohydrates and the chief source of the salts; and both kingdoms to be the sources of fats, without at present anything to show that the fats from either kingdom are superior or inferior in themselves to those from the other. Vitamins appear to be derived from the soil, directly or indirectly, by plants; they occur in animals only as their diet contains them. While necessarily widespread in all living plants and animals because essential to their nutrition, and therefore widespread in all foods derived from either plants or animals, they are more abundant in some plants and animals, in some parts of both, at some stages, than under different conditions; and are subject, as indeed are other important food bodies, to loss or destruction in preparation processes, which therefore require close supervision. Over-refinements of foods may perhaps produce physical as well as chemical or physiological disadvantages.

CHAPTER V

PRESENT IDEAS CONCERNING QUANTITATIVE AND QUALITATIVE FEEDING

According to foregoing statements, the first essential of a satisfactory diet is its *capability of supplying stored sun's energy to the body.* But ordinary coal, wood, and such materials burned in our household furnaces and stoves, do just this. They supply such energy in the form of heat radiated or conducted to the skin directly from the fire itself, or indirectly from the surroundings which have been directly warmed by the fire. Such heat is extremely useful at times in maintaining body temperature and in reducing the rate at which the body would have to produce heat were it not thus supplied. But the external sources of heat, including the direct light of the sun itself, supply heat only; and from the outside only.

The second essential of a satisfactory food distinguishes it from external fuels inasmuch as a food is *capable of entering into the body itself in unburned form* and of burning up and yielding its stored heat in the ultimate body cell. Its heat is released within the body; it forms an internal fuel; and it introduces into the body not heat alone, but also actual substance, bulk, which forms, for the time being at least, a part of the body. Of the physical life of the body cells, we know that by a ceaseless conversion of material from one chemical state to another they accomplish their varied activities of motion, secretion, electricity, heat, production, etc. To all these changes, heat is essential; but so likewise is the actual

material which is to undergo the changes. *External sources* of heat can at most supply only the first of these; the *internal sources* of heat provided by suitable foods supply both.

One might imagine that if the body cells were once given sufficient food materials, they might never again need new material, that they might use the same substances over and over again indefinitely, sending them round and round the circle of necessary changes without requiring any new material to replace them; in other words, that if new increments of heat reached the body from any source, new food materials would be unnecessary.

To understand why the body can use a given particle of food but once, one must understand how the sun's energy is stored in food and how it is liberated.

Circulation of Heat

To begin at the beginning, ordinary coal throws out its stored heat by oxidation or burning, that is, by undergoing the chemical process of combining with oxygen, which it does with tremendous rapidity and with the radiation of much heat. After the combustion, there is left the now oxidized carbon in the form of carbon dioxid, and if the coal was pure carbon and is thoroughly burned, there is no other product. The heat it has produced has not been made anew at all. It has merely been *liberated* from the storage in which it was placed many millions of years ago when it was stored by the plant life of that time from the sun's rays of that day. The amount of heat which was originally required to deoxidize the original carbon and get it into a condition in which it would burn was the exact equivalent of the heat it now throws out in burning. If we take the carbon dioxid after burning the coal (which for simplicity we are assuming to be pure carbon) we shall find that every particle of the original carbon is

still present in it but is now combined with oxygen; and that the total weight of the carbon dioxid formed is exactly that of the original coal plus the weight of the oxygen which has combined with it. Moreover, if we now desire to burn our carbon again, we must recover it in its original uncombined state; and we can do so if we are willing (and able) to supply to the carbon dioxid the *same heat* which was thrown off in its formation. If we do this we drive apart the carbon from the oxygen and then we are back again exactly where we started with the same carbon again in condition to burn and the same oxygen again ready to combine with it; that is, to burn it up.

It is evident that such a series of procedures of burning up carbon to evolve heat and then using the *same heat* to decompose the carbon dioxid so that we may burn the carbon over again would get us nowhere. Not a single particle of the heat evolved during one burning could be used to warm ourselves or for any other extraneous purpose; for any heat so used would create a shortage in the heat required to break up the carbon dioxid for the next burning and we should be unable to recover a proportionate amount of our coal. Thus it is evident that while we may use the identical materials, carbon and oxygen, over and over again, we cannot do this unless we are willing and able to supply from some source heat enough to break them up from their combination after each burning. If the heat evolved in one burning is used for extraneous purposes and we wish to decompose the carbon dioxid produced, we must have a supply of heat other than that derived from the burning. We may get it from other coal, from gasoline, or from other substances where it has been stored by the sun, or we may get it from the sun's rays themselves. If, however, we must turn to one of these new sources to get the heat we require to revamp our burned-out coal, why not use the new source for the purposes for which we intend to use our revamped coal, and so save all that unnecessary

labor? In practice this is exactly what we do. We buy our coal, burn it once, use its heat for warmth, for driving engines, and for other purposes, and discard the oxidized products; then for further burning we get new coal instead of attempting the perfectly possible but fearfully expensive and entirely unnecessary rehabilitation of the ashes.

The body follows this same plan, securing its "coal" in the form of food, burning it, and discarding the waste; then securing more "coal" in the form of food, burning it and discarding the waste. In this way the body not only follows the process most economical for itself but also, as a matter of fact, the only one open to it. The chemist may at great expense and with special apparatus, dislocate carbon from its combination with oxygen and use it as fuel again. But the animal body cannot do this. The carbon dioxid which the body throws out as a waste product is truly to it a waste product. The body cannot revamp it and use it again. Such carbon dioxid is not, however, lost to the animal kingdom forever, since plants have the power to build it up again into fuel useful not only to themselves but to animals that may eat them also.

Calorific Values

In dealing with heat and heat exchanges, the conversion of heat into energy and of energy into heat, in comparing the fuel value of different fuels and of different foods, we quickly recognize that there are quantitative differences in heat, that one fuel contains much more heat than another, that one pound of coal will not of course yield as much as two pounds of the same coal but may yield as much as two pounds of another kind. All these observations stimulate the desire to have a simple way of measuring heat in order that different heat values may be readily expressed and compared.

The thermometer registers the degree of heat but not its bulk. Thus a blowpipe flame is far hotter than is an ordi-

nary coal furnace flame but it would not, like the latter, heat a hotel. Imagine 1000 pennies all heated to a low red heat. One penny will show exactly the same temperature as another by the thermometer (which measures degree or intensity of heat); and the thermometer will register the same temperature for one penny by itself or for the whole thousand in a heap. But the *amount* of heat in the heap of such red hot pennies is obviously 1000 times as great as the *amount* of heat in one such penny. This may easily be demonstrated by comparing the effect of dropping one red-hot penny into a pint of water with the effect of dropping the whole thousand red-hot pennies into it.

The Small Calorie. The standard of measurement adopted for *amounts* of heat is the *small calorie,* which means the amount of heat required to raise one cubic centimeter of water one degree centigrade. This amount of heat, if totally converted into energy, would lift a weight of one gram (which is just the weight of one cubic centimeter of water) 426 meters.

The Large Calorie. The heat values of food are so great that they would require very large figures to express them in this unit, so we use instead the *large calorie* which is just one thousand times as great; that is, a large calorie is the amount of heat required to raise one thousand cubic centimeters (or one liter) of water one degree centigrade. Whenever calorific values are mentioned in food work, the large calorie is meant unless the small calorie is specified. Of course the energy equivalent of the large calorie is one thousand times as great as that of the small calorie, and therefore one large calorie represents heat enough to lift one kilogram (the weight of a liter of water) 426 meters.

How the Heat Value of Food Is Determined. The heat value of any food may of course be determined for that food in its native state; thus one might determine the heat value of an apple or of a pound of beefsteak or of a walnut. This would be done by enclosing a definite

quantity, say of the apple, in a container so arranged that every particle of heat that may be generated by the burning of the apple may be devoted to warming a definite quantity of water surrounding the chamber in which the combustion is to be conducted. Oxygen is supplied in pure form to the chamber, and ignition is accomplished by an electric spark. The rise in temperature of the water is watched by means of very delicate thermometers.

A simpler and better way of obtaining just as accurate results is to determine in the above manner once for all, the full vlaues of protein, of fat, and of carbohydrate; then by analyzing any meat, fruit, nut, or other food, and getting the *percentage composition* in terms of protein, fat, or carbohydrate, or any two or all three, we can determine the total heat value of the food by merely applying the heat values already obtained for each of these constituents in the proportions in which the analysis shows them respectively present.

Thus the fuel value to the body of *starch is four* (*large*) *calories per gram; that of protein is also four calories per gram,* while *that of fat is nine.* (Rubner's figures are 4.1, 4.1 and 9.3 respectively; Atwater's are 4.0, 4.0 and 8.9 respectively.)

This means that starch when completely burned in the body by oxidation to carbon dioxid and water (which are the ashes of starch, its waste products which the body discards) produces per gram enough heat to raise 4 liters of water one degree C., or 1.8 degrees F. Hence an ounce of starch, about 28.3 grams, when burned in the body gives out heat enough to raise four pints of water from body temperature to the boiling point. If used as energy instead of heat, this yield would be capable of lifting a 200-pound man 1300 feet. An equivalent weight of protein would furnish equivalent heat or energy, while an equivalent weight of fat would furnish about two and one-fourth times as much.

Number of Calories Required in Diet

These facts suggest at once a method of determining fairly accurately the total daily food requirements of the body, so far as fuel value is concerned, by finding out how much heat the body produces in a day; just as we might calculate the amount of coal needed in a furnace per day by determining the amount of heat which the furnace throws off in a day and thence calculating how much coal per day is necessary in order to keep up that amount of heat.

Determinations of the amount of heat thrown off by the body have been made in a number of ingenious ways but the most satisfactory is in principle quite equivalent to the method used in determining the calorific values of protein, starch, and fat as described above. The man to be experimented on is surrounded by water, supplied with oxygen, and allowed to "burn" in the way in which he ordinarily does. The heat which he thus produces is determined from the warming of the water which surrounds him.

It is thus ascertained that an ordinary adult man doing nothing yields about 1800 calories of heat in twenty-four hours. This is the heat required to keep the body engine running, even while at rest. It represents the energy expended in the heartbeats, the respiratory and intestinal movements, in maintaining the muscle tone, (⅓ to ½ the total); in secretion and in other internal operations, the cessation of which would mean death or great damage. A human body thus at rest may be compared with an automobile when idling, that is, when the engine is running but not in gear, so that the engine wheels turn, the fan revolves, the water circulates, the gasoline flows, and so on, but no external movement or work is accomplished. In cold weather automobiles are often allowed to idle in this way in order to keep the machinery warm and ready for work

when work is desired. If an automobile in cold weather out-of-doors were shut off from running, it would soon become so cold that it would not easily be set running again. But the human cannot of course be "shut off" in this way. It would not "start" again, easily or otherwise. Hence the human machine must be kept "idling" all the time that it is not at work.

Basal Metabolism Figure. The analogy with the human body, not only in cold weather but at all times, is obvious. The heat thus put out by the body while "idling," usually stated as "at rest," is called the *basal metabolism* figure; it shows the requirements of the body for its own operation alone while doing nothing actively to expend energy on the outside world. It is the analogue of the amount of gasoline required to keep the automobile idling. A very simple calculation will show that this "basal metabolism" figure is equivalent to the amount of heat yielded by one pound of starch, completely burned; which of course is equivalent to a pound of protein, or a little less than half a pound of fat. When any form of exercise is taken, even to the slight extent of turning over in bed, the heat output increases.

Metabolism. An ordinary man at ordinary manual labor yields about 3300 calories per diem, the soldier on active field service yields up to 5,000 or more. The surplus over 1800 may be considered as representing work. It is due to an increase in the rapidity and extent of the same tissue changes that go on during rest. *Metabolism* is the name given to the whole series of such changes involving the oxidation of foodstuffs, the repair and growth of tissues, their breaking down in the activities of the body. These changes differ in amount but not in kind from the changes needed to enable the body to accomplish changes in the outside world—to do "work." *Basal metabolism* is the name given to those changes when devoted merely to keeping the human machine running.

Quantity of Food Required to Supply Calories

Loss in "Food as Purchased." In selecting a diet which will supply the required calories for an adult for a day, it is not sufficient to find in a reference table one or more food products which provide the total number of calories desired, and then order the requisite number of pounds or grams of meat, vegetables, or other foods, which have been selected. Supposing a meal is planned to furnish 3300 calories to each person at the table; some of this *food as purchased* does not reach the table at all because of the various portions discarded in preparation for the table, so that the *food as served* contains perhaps but 3000 or so of the original 3300 calories. The loss is evident to every one; it passes to the garbage can in concrete form. Another loss occurs, however, in the body itself, due to incomplete absorption from the intestine of that food which is actually swallowed. This loss is in general placed at about ten per cent of the food as eaten. Of course the diners may not actually swallow all that is placed before them, and this *table waste* also must be watched. If one wishes to assure 3300 calories to each diner, he must provide about 3800 calories per head, and even then the diners must be persuaded to eat it all up, leaving nothing on their plates.

Appetites. It is at this point that the value of attractive preparation, good flavoring, and pleasant surroundings become of direct importance to quantitative feeding. "Appetite is the best sauce." Exercise, or outdoor life even without exercise, usually ensures that food roughly prepared and crudely served is eaten up "clean" and often followed by a cry for "more." A cry for more under these circumstances is likely to voice a real demand of the body and indicates that the dietitian may have underestimated the actual calorific output of his clientele.

On the other hand, very refined preparation, service under very æsthetic conditions, exquisite flavoring, and such like adjuvants may be carried to the point where a cry for more is not the demand of healthy appetite, but a psychic desire to continue further the incidental pleasures of dining, long after the real demands have been completely met.

Proportions of Protein, Fat, and Carbohydrate in Diets

General Data from Experience. Granting that the general experience of mankind indicates that a mixed diet is on the whole the most satisfactory for the human body, it would seem that there must be some certain mixture better than others, some formula to which the proportions of protein, fat, carbohydrate, salts, and water should adhere. Since man has solved the problem in past ages sufficiently well to sustain life, a survey of his food habits should throw some light on the question.

But man, scattered in different races from the equator to the poles, and until recent times without facilities for transportation, or knowledge of the things to be transported or of the places to transport them to, was compelled to live on what he could obtain in his own vicinity rather than on what he might choose among all the products of earth. His food habits are therefore likely to be the reflection of his environment rather than the expression of a guiding instinct to which we may turn with confidence. The Inuit, for instance, uses no carbohydrate, practically speaking, not because his experience has taught him to avoid it, but because he cannot get it in his country. The East Indian and the Chinaman in great numbers live largely upon plant life, not because they have learned that animal food is harmful but because animal food, except perhaps butter, is available to but few of them. Which

is the more physiologically successful? Both have survived under the conditions imposed by their surroundings. Which one has survived more successfully from a biological standpoint, it would be impossible to say without long continued statistical records, unavailable of course, relating to birth rates, death rates, average age at death, and similar facts; such records, if available, would require the closest scrutiny concerning cause of death, prevailing non-fatal diseases, and the history of the people apart from the food, in order that dependable or even plausible deductions might be made.

Dismissing as inadequate the evidence concerning proper dietary proportions obtainable from such food-limited peoples, we naturally turn to the great modern nations who control vast areas, possess huge transportation systems, conduct enormous trade exchanges with each other, and thus have access to the food products of all the world. Here, if anywhere, experience and observation may be supposed to have arrived at some sort of concensus of opinion. But even here the rich variety of food products thus made physically available to all is not financially available to everyone. A free biological choice cannot be exercised because it is hampered by the necessity for economic choice. Attention is diverted from food by standards of living other than those related to food, the expenditures required to meet social standards in education, dress, amusement, home and home equipment, the actual requirements for house fuel, and by the taxes demanded to sustain the whole fabric of modern civilization. In order to live more liberally in dress and other features which are subject to the inspection of their neighbors, many a family lives poorly on food which is not subject to such inspection. Actual starvation even to the point of death is not unknown in these countries, although it is never due under ordinary conditions to a general shortage of food, but to financial inability on the part of few to ob-

tain it. Transportation and trade equalize the uneven distribution of crop developments over wide areas and thus prevent the famines that were such a menace to earlier peoples, but the food habits of modern man cannot therefore be considered as yet wholly the result of free choice responsive only to instinct or to the dictates of experience as to what is truly best.

With all these *pros* and *cons* to consider, the study of human rule-of-thumb practice as a guide to proportions or to amounts is much less simple than at first sight might appear and the findings are proportionally less conclusive. Nevertheless, such studies extended over wide areas and among widely differing classes of people, do furnish a guide if not to what is best at least to what is good. This applies of course to such areas and to such classes of peoples as show no definite food diseases, and applies best to those areas and to those classes where the birth rates, death rates, and other biological data indicate at least a fair biological status. From such sources, figures have been compiled which show interesting results.

Data from Experiment

The empiric method just described has been supplemented to some extent in human circles and extensively among domestic animals by the *experimental method,* the actual feeding of groups under close control, various foods in various proportions and amounts, noting the effects in various biological directions. The difficulties in human experimentation are very great. Armies and institutions naturally suggest themselves as ready-made fields for such experiments; but armies and institutions exist for purposes not always compatible with such experimentation. Established food habits, prejudice, sentiment both within and without the group concerned, and of course the eternal question of finance, place rather narrow limits on

the range of combinations which may be tried. Again, though experiments on animals are more controllable and exact, the facts they disclose are not by any means always applicable to man, or even to all lower animals. For practical purposes, direct experiments on man are of far more importance than those made on other animals. But we cannot yet say that the final truth has been conclusively reached.

Proportions of Proteins, Fats, and Carbohydrates by Weight. As already pointed out, if the calorific value of food were the only point to be considered, the dietitian might find some one food product,—meat, vegetable, or a derivative of either—which in itself contains the needed calories. Thus two pounds of starch furnish about 3600 calories, and as starch loses little in preparation, this amount as purchased would probably provide the required amount as finally absorbed. The problem of serving it in acceptable form might be solved by a skillful cook, and thus the whole requirement would be met. But while one or two or three meals of this character might be successful, complaints would soon arise, first on account of the monotony, and later because of the real insufficiency of the diet. Starch, although supplying the calories fully, is wholly different from protein in lacking nitrogen, and is therefore a total failure as a repair or growth food. In adults this deficiency would not show itself so soon as in children, for the quite obvious reason that the protein demand of children, actively growing as they are or should be, is more insistent.

Without laboring the point beyond this indication of the difficulties to be met, let us concede that our calories must be drawn from the three foodstuffs, protein, fat, and carbohydrate. But in what proportions? Without being able to offer any satisfactory fundamental reason for it, the proportions which have been found to give fairly general satisfaction to consumers, and which may be main-

tained over long periods without complaint, are *fats, one part; proteins, two parts; carbohydrates, twelve parts, by weight.* Thus, whatever be the total weight of these foodstuffs in a dietary, about one fifteenth should be fat, two fifteenths should be protein, and the remainder should be carbohydrate. This does not mean that every meal must be thus proportioned or that all the meals in the day should always, when put together, work out as described; but for average adults, this in the long run should be the general formula observed. Modifications for extremes of age, exercises, and other circumstances, should be made; but in general, diets for mixed companies should present the features given, individual differences in requirements being met by individual variations in the food actually consumed at the table. A diet in which the constituents show the above relations is called "balanced."

In selecting the foods which are to yield the starches and fats, plant forms must be taken for the former, and either plant or animal for the latter; but in selecting the foods which are to yield proteins, the relatively low quality and absorbability of plant proteins make it well to discount about fifty per cent of the amount of protein available from plant sources; that is, to consider 100 grams from vegetable sources as the equivalent of only 50 grams from animal sources, for nutritive purposes, although the *calorific* value, gram for gram, is equal. It is advisable also to see that at least some of the protein in the day's ration is derived from animal sources, especially where children are being fed. Since *fat* has about two and one fourth times the fuel value of carbohydrate, it furnishes when present in the dietary in the above proportions, not one fifteenth of the *total calories,* but about one seventh; the *protein* furnishes about *one eighth;* the carbohydrate about *three fourths.* Atwater, the great American authority, suggests protein 1, fat 1, and carbohydrate about 3, the protein thus furnishing about one sixth of the

calories, the fat about one third, and the carbohydrate the rest.

Method of Calculation. To achieve the basal metabolism of the resting adult, about 1800 calories per diem is called for. If derived from a dietary modelled on the proportions first laid down, about 250 calories should come from fats, about the same from proteins, and the remaining 1300 or so from carbohydrates. To ensure that the 1800 calories are absorbed, in other words to allow for wastage, there should be from 2000 to 2200 calories present in the food as purchased, which should therefore consist of fat sufficient to yield approximately 275 calories, protein to yield about 250 calories, and carbohydrate to yield about 1500 calories, or even ten per cent more all round.

But this is not yet the whole story.

Since one gram of fat yields about nine calories, and a gram of protein or carbohydrate yields about four calories, a dietary figured to yield 2000 calories would require approximately 30 grams of fat, 60 grams of protein, and 375 grams of carbohydrate,—about sixteen ounces in all. This does not mean sixteen ounces of food as purchased, but sixteen ounces of pure fat, pure protein, and pure carbohydrate. Fat and carbohydrate may be purchased in practically pure forms, as starch and olive oil, for instance; but protein cannot at the present time be bought at the grocer's or butcher's as protein, but only as a constituent of eggs, meat, fish, bread, vegetables, milk, or other food.

As a matter of actual practice, fats and carbohydrates also are commonly bought, not pure, but as constituents of various foodstuffs, fats being obtained largely from meats, nuts, eggs, and milk; and carbohydrates from vegetables, cereals, milk, and nuts. In all these foods, the presence of more than one of the food principles complicates the process of obtaining them in right proportions;

while the presence of relatively large quantities of water as well as of some salts, makes it inevitable that the weight of the *food* should be double or more than double the weight actually wanted of protein, of fat, or of carbohydrate. Thus, about eighteen per cent of beefsteak is protein, eighteen per cent fat, sixty per cent water, and the remaining four per cent salts and other substances. It takes about 330 grams of steak to yield a required 60 grams of protein; but 330 grams of steak yield also 60 grams of fat, one-half of which, therefore, will have to be removed; the remaining 210 grams of steak is largely water, which is acceptable in forming part of the total body requirement of water, and makes the meat itself soft, pliable, and easy to masticate.

We must still provide carbohydrate, however, and unless we turn to a pure form like sugar or starch, we shall find it mixed, as for instance in potatoes, with protein and even a little oil; this makes it necessary to go back to the protein and fat which we have already provided in proper amounts, and reduce them to make up for the protein and fat unavoidably acquired in adding the carbohydrate. Troublesome as all this is, it needs to be worked out only once for each combination and is not as difficult in practice as it appears in describing it.

Illustrative Calculation

Body Requirement 1800 calories		*Required Provision* 2000 calories
Proportions:		
Fats	250 calories	275 calories or 30 grams
Proteins	250 calories	250 calories or 60 grams
Carbohydrate ..	1300 calories	1500 calories or 375 grams

If evenly divided among three meals, each meal requires 10 grams of fat, 20 grams of protein, and 125 grams of carbohydrate.

EXAMPLE: *Luncheon*

	Weight	*Protein* Grams	*Fat* Grams	*Carbo-hydrate* Grams
Macaroni	4 ounces	15.20	1.0	84.00
Cheese	½ ounce	4.08	5.9	.04
Tomatoes	5 ounces	.42	.28	3.11
Muskmelon	8 ounces	1.36	...	21.13
Sugar for coffee.....	2 lumps	....	...	14.2
Cream for coffee...	1 ounce	.8	5.6	1.4
		21.86	12.78	123.87

QUALITATIVE SELECTION OF FOODS

The foregoing discussion deals almost entirely with the fundamental requirement of calorific values, without which food must necessarily be a failure. But it may fail also if salts are not present in sufficient quantity, if the preparation and flavoring discourages appetite and digestion, and if vitamins are lacking. The absence or shortage of these essentials is a frequent cause of malnutrition or disease.

CHIEF SHORTCOMINGS OF ORDINARY DIET

In North America, the chief dietary error at present is a too great reliance on the ordinary staples,—muscle meat, potatoes, white flour bread,—which furnish the needed calories, but are short in salts and vitamins. By interrupting our routine of chops, steaks, roasts, bacon, ham; by not infrequent changes to liver, kidney, pancreas, and similar glands; by adding some leafy vegetable to our usual potatoes, turnips, and parsnips; and by using such foods as milk and milk products, eggs and fruit along with or as a substitute for the extraordinarily prevalent

cereal breakfast, we shall secure more vitamins and salts without detriment to the essential fuel and building stuffs.

Summary

In practice, the transmitting of the sun's energy to the body in forms which the body can use for its own life processes, for growth and for repair, is accomplished only by the very familiar and very commonplace procedure of eating "three square meals" a day. How this very ordinary process, often looked upon by the thoughtless as more a form of amusement than a serious life function, accomplishes the great ends of nutrition can be explained only by certain considerations of chemical and physical facts relating to the convertibility of heat and energy, the nature of burning, and the possibilities inherent in the rehabilitation of the ashes left after burning. The processes which go on in the body cell are thus shown to be identical in principle with those which go on in an ordinary domestic furnace and to result in similar and sometimes identical waste products.

In order to deal concretely and exactly with such problems, it is necessary to have units for measuring heat and its energy equivalent. The heat unit selected is the *calorie*. The amount of heat given out by different substances undergoing oxidation or combustion has been determined in terms of the calorie. In the same way we may determine the daily heat output of the body, and recognizing that this heat output must be daily restored if the body is to continue living, we have a ready means of determining what the daily income of the body should be in calories or food. Knowing the calorific values of different foods, we may readily calculate the total amount daily required for the body either at rest, that is, when burning only what is required for its own internal operation, or when

also engaged in external work of various degrees of strenuosity.

But the problem is not thus entirely solved, for the demands of the body, though clear enough so far, are complicated by the empiric finding that although any one of the three foods, carbon, fat, or carbohydrate, may supply perfectly and abundantly the heat units required, the modern body demands all three kinds for its successful operation. Moreover, there is a certain more or less "best" proportion in which these fuels should be combined.

Beyond these basic quantitative considerations, there are qualitative considerations of almost equal importance. Food must be *quantitatively* correct to permit life; it must be *qualitatively* correct to permit health. The most important of the qualitative problems is that related to the amounts and kinds of proteins required to replace the broken down proteins of the body, that is, to repair waste and constitute growth. Minor problems relate chiefly to the salts and vitamins necessary.

The *shortcomings of American diets* are not due either to a lack of building value or of fuel value, but to a widespread shortage of salts and vitamins, or rather of the foods now known to be richest in them, to a predilection for over-refined and concentrated food, and to a tendency to prefer protein of vegetable origin to those of animal origin which are more useful and complete, especially for children.

Although in the northern part of the continent no serious or prevalent disease can be traced to poor food habits, certain diseases in mild form, such as *scurvy* and *rickets,* are by no means uncommon; while in the southern part of the country, *pellagra,* a very definite disease traceable to poor dietary, exists extensively in serious and even fatal forms.

On the other hand, *simple malnutrition* is everywhere to be found, and if we accept that definition of malnutri-

CHEMICAL COMPOSITION OF COMMON FOOD*

Food Material	*Water* Per Cent	*Proteins* N× 6.25 Per Cent	*Fat* Per Cent	*Carbohydrates* Per Cent	*Ash* Per Cent
Animal Food					
Bacon, smoked	20.2	9.9	64.8	....	5.1
Beef, roast, cooked	48.2	22.3	28.6	....	1.3
Veal cutlets	70.7	20.3	7.7	....	1.1
Pork, ham	40.3	16.3	38.8	....	4.8
Chicken, fowl	63.7	19.3	16.3	....	1.0
Bass, black	74.4	19.4	4.9	....	1.5
Salmon, dressed	63.6	17.8	17.8	....	1.1
Eggs, boiled	73.2	13.2	12.0	....	0.8
Whole milk	87.0	3.3	4.0	5.0	0.7
Butter	11.0	1.0	85.0	....	3.0
Cheese, cottage	72.0	20.9	1.0	4.3	1.8
Bread and Meals					
Corn meal, granular	12.5	9.2	1.9	75.4	1.0
Oatmeal, gruel	91.6	1.2	.4	6.3	.5
Rice, boiled	72.5	2.8	.1	24.4	.2
Wheat, bread, white	35.3	9.2	1.3	49.7	1.1
Graham bread	35.7	8.9	1.8	49.8	1.5
Cake, cookies	8.1	7.0	9.7	68.5	1.5
Vegetables					
Asparagus, cooked	91.6	2.1	3.3	29.1	.8
Beans, string	89.2	2.3	.3	7.4	.8
Cabbage	91.5	1.6	.3	9.3	1.0
Celery	94.5	1.1	.1	19.7	1.0
Carrots	88.2	1.1	.4	3.3	.9
Corn, green	75.4	3.1	1.1	3.1	.7
Peas, green	74.6	7.0	.5	62.0	1.0
Potatoes, cooked	75.5	2.5	.1	27.4	1.0
Spinach	89.8	2.1	.3	3.2	2.1
Squash, cooked	88.3	1.4	.5	9.0	0.8
Tomatoes, fresh	94.3	.9	.4	3.9	0.5
Fruits					
Apples	84.6	.4	.5	14.2	0.3
Oranges	86.9	0.8	0.2	11.6	0.5
Peaches	89.4	0.7	0.1	9.4	0.4
Pineapples	89.3	0.4	0.3	9.7	0.3
Prunes	22.3	2.1	...	73.3	2.3
Strawberries	90.4	0.1	0.6	7.4	1.0

* From Proudfit—*Dietetics for Nurses.*

tion which makes standard weight for height and age the standard of nutritional health and ten per cent departure therefrom, the standard of definite deficiency requiring treatment, then about thirty per cent of our school children are suffering from malnutrition.

PROJECTS FOR CHAPTERS III TO V

1. If you were able to send a consignment of food to the starving *children* of some famine-stricken or warring nation, what products would you choose and why? Estimate the cost of a ship load.

2. You are a visiting nurse and a physician places under your supervision a child twelve years of age who is suffering from constipation as the result of faulty habits of living and improper diet. Make out a comprehensive program of diet, sleep, exercise, for the child for one week.

3. Outline in detail the instructions that you would give for the care of the teeth to a family of foreigners whose knowledge of English is quite limited. Keep in mind the fact that these people must be convinced of the necessity of caring for the teeth, and that simple language, demonstrations, and pictures will be necessary helps in the project.

4. Prepare for children of the Fifth Grade a health pamphlet that deals with the care of the teeth.

5. Devise for the class room a wall chart that will show foods that are rich in protein; in carbohydrates; in fats; in minerals.

6. Present to the class a report on the experiments that have been made to determine the relation of vitamins to general health.

7. Formulate "rules of health" that may be deduced from these chapters on nutrition.

8. Construct a graph that will show the comparative estimates of physiological needs for food, expressed in calories, for children of different activities during the first fifteen years of life.

9. What are the conditions under which you are likely to contract beri-beri? Prepare a report regarding the cause of this disease and the treatment of it; include descriptions of actual cases.

10. Formulate a set of rules for restaurant employees, mothers, nurses, and others who serve food, with a view to the prevention of disease transfer. Give your reasons for each rule.

11. Demonstrate the fact that chlorophyll plants manufacture starch and that sunlight is necessary for the process. Prepare an explanation of the process for presentation to the class.

12. What arguments would you use to convince the members of your class of the value of cleanliness in the care and handling of milk? Explain to them in detail how and why milk should be cared for and handled.

13. Demonstrate and discuss the various methods of cooking as related to hygiene.

14. Make out a balanced diet for one day for yourself, for a patient, or for a member of your family.

15. Name four "dishes" each of which would be a balanced meal in itself. Explain. Prescribe a sandwich of bread and meat which shall in itself be "balanced."

16. Prepare a menu for one day for one of the following: a student; a football player; a growing child; a sedentary; a laborer in the field; an obese; an anemic; an aged person.

17. Make a study of the manner in which nervous conditions affect digestion. Report on your findings and observations.

18. If you were a Public Health Nurse, how would you advise a mother about the care of a child that has a tendency to rickets? How would you convince her of the necessity of the régime you recommend?

19. What are the conditions under which scurvy develops? Outline a definite plan for its prevention among sailors.

20. Outline a plan for an educational campaign among southern negroes to convince them of the necessity of taking measures for the prevention of pellagra, and to teach them the necessary measures.

21. Make a study of the problem of economy in food and cookery as related to variety in diet.

22. Subjects for debate:

Resolved that:

Vegetarianism is to be recommended.

Avoidance of alcohol makes for national health.

CHAPTER VI

THE CONVERSION OF FOOD INTO BODY SUBSTANCE

THE STORAGE AND LIBERATION OF ENERGY. The outstanding *physical feature* of living substance is its incessant, rapid *interchange of material with the world outside of itself* for the purpose of renewing itself and its supplies and of ridding itself of its waste. Its outstanding *chemical feature* is its incessant, rapid *change in internal composition* for the purpose of carrying on its life processes. These consist chiefly in building into itself materials (food) capable of forming active living substance (protein) and of furnishing heat (therefore energy) in usable forms, and in oxidizing these materials in different degrees until by various chemical routes their energy has been elicited and they are no longer of value to the body. The upbuilding processes are known as *anabolism*; the decomposition processes (largely combustion), as *katabolism.*

The analogy between these life processes, complex as they are, and the simple burning of carbon is very close. Carbon, taken by itself, is an inert and changeless substance, which nevertheless possesses a great *potentiality* for combination with oxygen. At ordinary temperatures it remains practically unaffected by oxygen, but if the temperature be raised to the "ignition point," combination with oxygen present begins and thereafter proceeds with tremendous energy (or heat). The resulting substance, carbon dioxid, is merely the composite formed by the union of the carbon and oxygen in certain definite propor-

tions,—one atom of carbon to two atoms of oxygen, or CO_2. Once thus combined to this extent, the carbon cannot combine further with oxygen and therefore cannot produce further heat (or energy) in that way unless and until it is freed from that combination. To set it free requires that exactly the same amount of energy (or heat) be supplied to tear down the combination as was evolved when the combination was formed. Its condition may be illustrated by an unwound clock-spring, which is inert and useless for the production of energy until new energy is imparted to it by winding it up again. The potential energy thus stored in the new wound-up spring may then be released to revolve the hands of a clock. Careful measurements show that it requires exactly the same amount of energy to wind it up as was evolved in its unwinding. The energy thus stored in an ordinary household clock is so small and the heat equivalent so low, that we can easily spare it from our bodies without noticing any difference; and we actually do this when with a few turns of the wrist we supply to the spring in a moment or two the energy which it will slowly pay out again during the subsequent day. But the amount of energy needed to wind very large clocks may be so great as to require machinery driven by steam or electricity which in turn derives its energy from the heat stored in coal, gasoline, or similar fuel.

Exactly so is heat stored in the body and released as energy, the high-power materials becoming low-power materials as they give out their energy. In restoring energy to the body, however, it is much more economical to replace the unwound springs (broken down proteins, carbohydrates, and fats) with new ones than to rewind the old ones. The unwound inert springs (waste products of the body) are then, so to speak, sent back to the *energy-storing factory,* the plant world, to be re-wound and in time are returned to the animal energy-evolving factory

for unwinding. A very complete analogy is found in the charging of electric storage batteries for use in electric motors. This is done at the storage station at frequent intervals, the automobile then using the stored energy until it is exhausted, when the batteries are again charged.

Physical Supply of Food to Body Cells

Logically, the mechanism by which food materials reach the body cell for use should be considered before the chemical changes which really constitute nutrition are described.

Water Insolubility of Food Principles. Human foods for reasons already given necessarily consist chiefly of plants and animals or parts of them. This means that these foods consist of protein, fat, and carbohydrate, in forms and combinations which while united with very large percentages of water are to a great extent insoluble in water. Otherwise, the definite forms which plants and animals have would be lost by solution, and instead of a beefsteak with its solidity and definite structure we should have only a sort of rich fluid to eat. A man, if he were not insoluble in water, would be merely a pool containing his various chemical constituents.

Living Cell Surrounded by Water. In order to transfer these insoluble food substances from the outside world where insolubility is essential to individuality, to the body cell seated deep in the structure of the insoluble body, they must either be introduced directly as insoluble particles or carried in soluble form through the water of the body. In the low single-cell animal, like the ameba, each cell of which species is in direct contact with the outside world, the taking-in of food in solid form is very simply attained by the cell protruding portions of itself around the food particle and then fusing these extensions again with the food particle inside; but if the food be in solution, it may "soak it up through its skin" without using these temporary arms (pseudopodia).

But neither the extension of itself to engulf the particle nor the soaking up process can take place unless both the ameba and its food are suspended in water. The moment a living cell ceases to be surrounded by water, it ceases to function and usually soon dies. Every cell of the human body which is truly alive is surrounded by water; the only body cells not so surrounded are the outermost cells of the skin, which have ceased to live by the time they have reached this exposed and relatively waterless situation. Of the total weight of the body, about seventy per cent is water which is so distributed throughout the body that every living cell is continually bathed in it much as the ameba is bathed in water of the outside world. Surrounded by this slightly salty water of the body (lymph) the living cell receives its food water-borne through the devious interstices between the cells whither it has arrived in the blood stream flowing through the body in definite channels (blood vessels). Leading into these channels there can be no openings to the outside world large enough to admit solid food particles, for the blood itself would escape through such openings. Moreover, most of the body cells have to a great extent lost their embryonic ability to engulf solid particles although certain body cells will do so under certain circumstances. Hence it comes about that the body cell is dependent to an enormous extent, if not entirely, on foods brought to it in solution.

Digestion. One of the first physical problems of nutrition is therefore the conversion of the water-insoluble proteins, fats, and carbohydrates of the food into water-soluble forms, in order that they may be capable of transfer by the carriage systems of the body to the cells which require and can use them. Conversion of these food materials from the insoluble state necessary to the existence of plants and animals as living individuals to the soluble states required by the animals that use the same plants

and animals as foods, is accomplished by processes which we call *digestion*.

Mastication

To the ameba only relatively small particles of solid food are available for the rather obvious reason that the ameba has but a small actual content of body-material which it may use to surround particles with. When the particles are too large to engulf, it must either use digestive fluids thrown out from itself to dissolve the food, or discard the particle altogether. But the larger animals and man have a wider range in the relative size of food masses available to them, for the claws and teeth of the tiger, the knife and the teeth of the man, enable them to reduce to sufficiently small sizes food which may at first be found too large for engulfment. Without these weapons man would be restricted in his diet to things already in solution and to such plants and animals as are in nature small enough to be swallowed whole, as oysters, radishes, or nuts. With knife and teeth, however, the entire animal kingdom and an extensive part of the vegetable kingdom are available to him,—"the whole world is now mine oyster."

Mastication is a further development of the size reduction process, not used much by the carnivorous animals which as a rule are content to swallow fragments reduced only far enough to permit swallowing. On the other hand, many of the gramnivores or plant-eating animals have carried mastication far beyond this point, probably because the extremely insoluble character of great portions of the plants they eat requires that the parts capable of solution in their digestive juices be squeezed out from the framework of insoluble cellulose in which they come to the gramnivores' teeth. The chewing of the cud is supposed to be particularly designed to this end.

Man, omnivorous in his diet, that is, eating both animal and plant, masticates both indiscriminately, protein perhaps too much or to an extent not really required, carbohydrates perhaps too little, to ensure maximum returns.

Mastication not only reduces the size of the particles to be swallowed, but also, by cooling hot foods and warming cold foods, tends to bring the food to the body temperature at least to some extent. It also helps to moisten the outer surface of the food particle, thus lubricating it for its passage down the throat. The glands of the mouth supply for this purpose not only water, but also a slippery body-protein, *mucin*. Starches are actually digested (rendered soluble) in the mouth to some extent, for the saliva contains a substance, *ptyalin* or *diastase*, which acts chemically upon some starches, converting the insoluble starch into the soluble dextrin, or still further, into sugar. The more thoroughly starchy food is comminuted in the mouth by mastication, the more thoroughly will the saliva penetrate to its ultimate particles, and, other things being equal, the more thorough will be the digestion. The incorporation with saliva of starchy foods in the mouth is therefore apparently a decided advantage, although the actual digestive changes probably occur chiefly in the stomach, the very brief stay of food in the mouth giving little time for extensive action there.

Fats as such hardly require mastication, but when they come to the table as parts of a meat food, they are enmeshed in fibrous protein tissue, the mechanical tearing up of which by the teeth may tend to make the separation of the fats from it at later stages somewhat more simple. Concerning protein, however, such ample provision is made in the stomach and intestines for the handling of it that there is question of the real advantage of its mastication. Making things easy for the body from the theoretical standpoint often results in some unforeseen loss of

ability in some unforeseen direction, and certainly the extremist view that even soup should be chewed, requires much more evidence than has yet been collected before credence need be given it.

Digestion, Absorption, and Assimilation of Starch

The Carbon Molecule. The chemical structure of carbon dioxid, CO_2, would appear to be of the simplest character,—the chemical union of carbon, one atom, with oxygen, two atoms. These are probably set together with the carbon atom between the oxygen atoms, the carbon being united with each of the oxygen atoms independently and the oxygen atoms having no connection with each other except through the carbon. This may be visualized by the rational formula, $O = C = O$, in which the double lines connecting the carbon with the oxygen indicate the capacity for union of the oxygen atom compared with the hydrogen atom. Each oxygen atom has two such capacities, each carbon atom, four; in carbon dioxid all the capacities of each atom are fully satisfied, and therefore it is a stable compound.

Hydrolysis of Starch Molecules. The chemical structure of starch is far more complicated. Starch is chemically a *polymer,* or a body composed of a great number of like chemical units, the units themselves having a very complicated chemical structure. The units of the starch in which we are interested from the food standpoint are closely allied to the sugars available to the body uses. When the huge starch molecule is broken up by the physicochemical process of hydrolysis, it first breaks up into sugarlike units (dextrins), which are further modified slightly by the hydrolysis into true sugars. Each of these units, whether in the original starch molecule in a form close to that of sugar, or dislocated from the starch molecule by hydrolysis and so in the actual form of sugar, consists of carbon, oxygen, and hydrogen.

The proportions of these to each other, but not of course their actual chemical relationships, are those of a mixture of a number of molecules of carbon with twice the number of molecules of water.

The process of hydrolysis is not merely a direct and simple breaking down of the original molecule to its ultimate units. The first change is a splitting of the whole molecule of starch into *dextrin,* which is not the ultimate unit but represents *merely certain groups* of those units. The dextrin in turn undergoes hydrolysis and the result is another form of dextrin. This second form of dextrin hydrolyzes into sugar (*maltose*) which breaks down to the final unit, *glucose,* a simple soluble sugar. It is to this stage that digestion must go in order that the soluble unit thus obtained may be placed in circulation in the body fluids, and so reach the body cells with their stored energy and their own actual substance.

The hydrolysis of starch to a simple sugar is accomplished by the *ptyalin* or *diastase* of the saliva, but diastase is also found in the pancreatic secretion and is widely distributed throughout the body so that it is always at hand for its purpose when required. At first sight this might seem rather superfluous since starch does not and indeed cannot enter the circulation as starch but only as sugar, and hence it would appear that diastase in the body tissues would have no starch to act upon. But as a matter of fact, the sugar which reaches the circulation as such may be stored up if it is not at once required for fuel in the body; and when it is stored up, it is stored in its insoluble form as animal starch (glycogen) the change back (*dehydrolysis*) being accomplished apparently by diastase, the same substance which accomplished the original hydrolysis from starch to sugar. The purpose of diastase in the tissues then is to convert the sugar into stored starch and also back again into sugar whenever it has to be transported elsewhere for use.

Digestion, Absorption, and Assimilation of Proteins

The Protein Molecule. The protein molecule as we know it chemically after its death (it is impossible to analyze chemically any substance while it is alive) is a body composed of a great number of unlike units having nevertheless a certain family resemblance in chemical structure. These units belong to a general chemical group known as *amino-acids* and all contain, in addition to carbon, hydrogen, and oxygen, the distinctive element of protein—nitrogen. Just as insoluble starch is broken up by hydrolysis into its *like* constituent units slightly modified (sugar) and just as sugar is soluble in water though it was as starch previously insoluble, so insoluble protein is broken up by hydrolysis into its *unlike* constituent units which, as amino-acids, are also water-soluble.

Hydrolysis of Protein Molecules. The conversion of protein to its ultimate units, amino-acids, is, as in the case of starch, accomplished by a series of processes of hydrolysis representing a series of changes even more complicated than was noted in the digestion of starch. Thus the original protein is first hydrolyzed to a number of intermediate bodies, these to *peptones*, and the peptones finally to eighteen or twenty amino-acids. The amino-acids being water-soluble can then be taken up by the blood stream.

Assimilation of Amino-acids. The assimilation history of the amino-acids is somewhat similar to the assimilation of starch, but more complicated. Remembering that the amino-acid units of the protein molecule are not identical with each other as are the units of the starch molecule, it is easy to understand that every such amino-acid is not interchangeable with every other as the starch unit is, in its use in the body. To replace a given amount of broken-down body protein with food-protein the latter

must be reduced to amino-acid units. But it is necessary to have not merely a sufficient *total* of the amino-acid units; there also must be enough of *each kind* of amino-acid to replace the wastage of corresponding kinds which may be demanded by the body, the kinds demanded depending on the particular form and extent of the wastage which is to be replaced.

It is not difficult to imagine a situation arising in the body where a plentiful total intake of food-proteins may fail to match a decidedly smaller total wastage in the body because of a lack in the food of one or more types of amino-acids, although there may be a surplus in the food of other types. Under such circumstances the body could not do otherwise than excrete the useless types and hence actually would throw out nitrogen in certain combinations while suffering from a lack of it in certain other combinations. As a matter of fact, even in ordinary life, the proteins taken as food are not by any means completely used in the body. Some or all of the amino-acid arriving at the liver is broken up into a *nitrogen-bearing portion* and a *non-nitrogen-bearing portion.* A not inconsiderable portion of the former is excreted forthwith as urea. The rest of the nitrogenous portion is used to furnish the nitrogenous requirements of the protein of the body, and the non-nitrogenous portion (about 58 per cent of the total) which in general is of a carbohydrate complexion, is used like carbohydrates as a fuel. It is suspected but not yet demonstrated that the body may have a method of storing protein as it stores starch against future needs.

The Interchange Between Blood and Lymph

When the sugars or amino-acid fragments in the blood-stream, into which they have been absorbed from the intestine, reach the finest capillary blood vessels, they are still separated from the lymph and so from the body cells

bathed by the lymph, since the capillary vessel walls interpose between the blood streams and lymph at every point. Being in watery solution in the blood and being separated by the capillary vessel wall from a watery solution of different materials on the other side of that wall, the sugars and amino-acid fragments are in a position to pass through that cell wall by a process known as *osmosis* or diffusion through a membrane.

Osmosis. There are a variety of membranes, particularly of animal origin, which, if made into the form of bags, may be filled with solutions of sugar or other substances, including amino-acids, and will retain such solutions perfectly, without leakage, so long as the membrane is dry on the outside. If now such a solution-filled membrane is immersed in a solution of exactly the same character and strength as that which it contains, there begins at once through the membrane of the bag an exchange from the solution within the bag to the solution outside it and vice versa both of water and of the substances held in solution. Since in this instance we are supposing that the solution inside is identical with that outside, this exchange will not affect the character, strength, or amount of either solution. But if to either, the inner solution alone or the outer solution alone, a diffusible substance be added, as soon as it is dissolved it will begin to pass through the membrane to join the liquid on the other side which has none of this substance in it. The ultimate situation arrived at is an equal distribution of the new substance so that both solutions will have equal strength throughout as if no membrane were present. In this effort at unification, so to put it, not only does the diffusible *substance* pass from the stronger solution to the weaker solution, thus adding substance to one while subtracting it from the other, but the *solvent* (the water) passes in the opposite direction from the weaker solution to the stronger solution, thus concentrating the one and diluting the other.

Since the water required for the solution of the substance is usually greater in bulk than the bulk of the substance it will dissolve, the water passes to the strong side more quickly, that is, in greater bulk, than the substance does to the weaker side. If we have added the substance to the solution in the bag, the bag will swell out with the inflow of water. If the substance is added to the solution outside the bag, the bag will collapse somewhat as its water flows out.

This process of osmosis can readily be seen at work in cells by withdrawing a drop of blood from the finger and placing it quickly, mounted under a coverslip, beneath a high-power microscope. If the mounted specimen is inspected promptly, it will show the well known bi-concave shape of the red blood-cell, because at the moment an equilibrium exists between the various substances in the liquid portion of the blood and the same substances within the red blood-cell. But as evaporation from the edges of the mounted specimen goes on (as it will unless precautions are taken to prevent it by sealing the edges with some such substance as vaseline) the liquid outside the red cells becomes by this concentration a stronger solution than that within the red cells. The water of the cells will then flow out more rapidly through the cell walls (which in this case constitute the membrane of our osmotic system) than the outside substances in solution will flow in. The cell therefore shrinks and becomes wrinkled or "crenated." If, however, at the beginning or even at this stage we add distilled or ordinary tap water to the specimen, we reverse the situation, for we thus dilute the liquid outside the cells in comparison with the solution within them and thereby cause a flow of water into the cells, which expands them and causes them to lose their bi-concave form and become globular, swelling to a larger than normal diameter or even bursting.

It is on the principles of osmosis that the blood stream

supplies the food substances to the lymph and removes from the lymph the waste products of the cells; and it is on the same principles that the lymph supplies to the cells the food substances thus obtained, and removes from the cells their waste products which it then passes on to the blood stream. Thus the blood, fresh from the intestinal wall, contains a higher percentage of foodstuffs than does the lymph which has been parting with its stores to the cells; while the cells, actively consuming their supplies, possess a still smaller concentration of the foodstuffs than does the lymph. The osmosis of foodstuffs is therefore inward, toward the cell. Exactly the reverse is true of waste products. The blood, fresh from the kidneys and lungs, is relatively free of waste products. The lymph, purifying itself continually into the blood stream, has more waste products than the blood but less than the cell. The cell, actively and continually consuming its foodstuffs and its own substance, is continually on the point of smothering itself in its own wastes. The osmosis of waste products is therefore from the cell outward. The blood as it enters the capillaries is charged with foodstuffs and other substances desired by the cells. It parts with these, accumulates the cells' waste products, and hurries on. Half a second is evidently the average time required for these changes, for this is the average time spent by the blood to pass through a capillary.

The Function of Water in the Body

It is now evident that water plays an immensely important part in the physics of the body. It provides for the gross transportation of food from place to place in the body; it makes possible the delicate *osmotic transfers* through semi-permeable membranes and notably through the membranes represented by the capillary walls and the cell walls; it furnishes not only the solvent for the food

and the wastes of the body, but also through hydrolysis the wherewithal to make insoluble substances soluble. It probably enters into even more intimate chemical relationships with the living protein molecule than any yet outlined; and it is suspected that, like proteins, water may be stored away in the body in ways not yet understood. It is certain at least that as in the body there can be no *life* without protein, so there can be no *activity* without water.

The History of Fat in the Body

As potassium, an alkali, combines with sulphuric acid to form a salt, potassium sulphate, so glycerol combines with certain *organic acids* to form *fat*. These acids are for this reason called *fatty acids*.

Fat as fat is notoriously insoluble in water, and therefore cannot be transported in solution or transferred by osmosis, like sugar or amino-acids, yet it must be had *in solution* somehow or it is valueless as food. The body meets this problem once more by means of digestion, and again by hydrolysis, conducted under the auspices of a *ferment* known as *lipase*.

The hydrolysis of fat does not break it up into a large number of like substances as in the case of starch, nor of unlike substances, as in the case of protein. Hydrolysis of fat produces *glycerol* and *fatty acids*, both of which are soluble in water. It is in these two forms that fat approaches the intestinal cells from the intestinal side, and it is in these two forms that it passes through the intestinal cells to be reunited in the blood or the chyle ducts on the other side, whence it is poured into the blood stream and circulates to different parts of the body. Following a fatty meal the blood may be quite milky for a short time on account of the fat thus undergoing transportation, not as a solid nor in solution but as one liquid floating in another. When the fat reaches the capillaries the problem of

how to pass through a membrane—the capillary wall—recurs and is again solved by *lipase,* which again hydrolyzes the fat to glycerol and fatty acids. In these forms it passes to the cell through the lymph. There the fat is sometimes dehydrolyzed and so reappears as fat, quite visible under the microscope. It is not improbable, however, that its two constituents are often used as food without recombination.

Surplus fat is stored, often in quite obvious quantities, under the skin and about the intestines, kidneys, and other organs. In such storage it consists of actual droplets of fat contained in cells which, for the time being, seem to serve only as storehouses. In these cells the droplets at first show as tiny spots, which accumulate, fuse, and finally form the bulk of the contents, the protoplasm of the cell remaining around the drop as the skin of an orange surrounds the pulp. When this stored food is needed, it must by hydrolyzed to glycerol and fatty acids before it can pass out of the cell to the circulation.

The History of Salts

Derived by plants from simple organic compounds in water and in the soil, salts are built up into the protein molecule. According to some authorities, most salts are of little direct value to the animal cell except in such organic combinations. However, McCollum of Hopkins is of the opinion that inorganic combinations may supply the salts needed by animals except in the case of sulphur which he believes must be furnished in organic combination. Iron is extremely useful in the body, for in the blood cell it has to do with the loose chemical combinations which permit oxygen to be picked up by the blood stream at the lungs and to be delivered to the cells at the distal capillaries. Calcium, magnesium, and other salts, enter into the structure of bone and have remarkable effects, not yet well

understood, upon the heartbeat and doubtless upon other activities of the body. Variations in the concentration of salts may have to do with maintaining the balance between water in the capillaries and water in the cells and lymph, but as yet little is definitely known concerning the minuter details of these reactions.

Summary

The great characteristic of living matter is incessant change, both internal, in composition, and external, in its relation to the outside world. One of its most important relationships to the outside world consists in deriving therefrom the materials necessary for its own structure and the necessary energy for its own activities. Another equally important relationship consists in returning to the outside world its waste products, otherwise fatal to itself.

The great chemical characteristic of the changes themselves is the oxidation of complex bodies to simpler forms, with the evolution of heat or its equivalent, energy. In the animal body little, if any, storage of heat takes place by deoxidation, as it does in the plant.

The insolubility in water of proteins, fats, carbohydrates, essential to the existence of living plants and animals as individuals, would prevent their being used as animal food were it not that the living animal body possesses ferments which render the dead body soluble, usually by the process of hydrolysis. This process does not alter the essential features of the foodstuffs nor does it require the expenditure of much energy; moreover it is reversible, so that they may be recovered by dehydrolysis, and be stored in the body in their usual form, at least in the case of carbohydrate and fat. Although the initial solution of food materials by hydrolysis on a larger scale takes place in the intestines, the same hydrolyzing ferments or their equivalents are found also in the tissues and operate there when required.

The first process which most foods undergo before being swallowed is reduction to fragments, primarily to permit swallowing, and secondarily, especially in plant-eating animals, to separate the parts of food from the unusable portions enclosing them. The succeeding changes in the food principles are the result of hydrolysis which renders them transportable in solution in the blood stream and permits osmosis through the barriers interposed by the vessel walls and the cell walls.

The blood stream does not take food directly to the cell nor remove waste products directly from the cell. The body cell is bathed in a salty water as the free-living single-celled ameba is bathed in the sea; and it is through this salty water (lymph) that all interchanges between blood stream and cell are made.

Fats and starches are stored in the body to supply future needs, and it is not improbable that proteins, salts, and even water may in some sense be "stored" also.

The uses of salts in the body are of great importance but very little is yet known of their history or functions.

CHAPTER VII

NUTRITIONAL HYGIENE: RESPIRATION

Since nutrition deals with all the changes by which the sun's heat and energy are converted into the heat and energy of the body, it includes not only the process already described, by which high-power fuels reach the cells where they are to be used, but also the process by which they are to be used. Briefly, this process is oxidation, but the process by which oxygen is brought to the cell is equally as important as is the process by which the foodstuffs reach the cell, although rather less complicated. If either food or oxygen be absent from the cell, nutrition ceases. Moreover, if the body as a whole be cut off from external food supplies, it may continue to exist on its reserve supplies for long periods, up to thirty or forty days (provided water be available), but if it be cut off from oxygen supplies, death ensues in a very few minutes, for the body has no oxygen reserve that will last through a prolonged period.

Character and Sources of the Oxygen Supply

Oxygen enters the body in two states. The first or combined state is that in which it is when it enters as a constituent of protein, carbohydrate, fat, salts, or water, for each of these contains oxygen as one of its combined elements. The second is that in which it enters as a free uncombined element, as oxygen alone, in its native condition as a gas. The oxygen which enters in the combined state is of no value to the body for the purpose of evolving

heat; for the heat of that combination has already been evolved, and cannot be evolved again, except by first dislocating the oxygen from the combination, and then allowing recombination. Such dislocation of oxygen from its combinations the animal body cannot accomplish; and to the extent to which oxygen combination already exists in the foodstuffs when presented to the body, the foodstuffs are unavailable to the body as fuel. It is because combination of oxygen with other elements in foodstuffs is not already carried to the full extent possible that further oxidation is possible; it is this further oxidation that the body employs to secure from the foodstuffs the heat and energy it needs.

The animal body cannot free oxygen from combination as the plant body can; and apparently it cannot initiate the combination of oxygen with any substance with which oxygen is not already partially combined. Invaluable as carbon, hydrogen, nitrogen, sulphur, and phosphorus are to the body, each a *sine qua non* of animal existence, not any one of them, nor any combination of them either amongst themselves or with other elements, is available as fuel to the body unless oxygen be present in the combination, *i.e.*, unless they are partially oxidized. On the other hand, they are useless as fuels if they are already completely oxidized.

Hence a satisfactory food for the body must be neither unoxidized nor completely oxidized. Moreover, while the body does oxidize carbon to carbon dioxid, and hydrogen to water, *i.e.*, both to complete oxidation, it does not oxidize nitrogenous compounds to the possible limit, but rejects them while still capable of further oxidation. To revert to the illustration of the clock-spring, the body cannot begin to avail itself of the energy of the spring until the spring is partially unwound, and at least in the case of the nitrogenous "springs," cannot avail itself of the energy set free toward the end of the unwinding.

The oxygen which enters the body in its free uncombined state as a gas is the oxygen which the body uses for combination with its fuel, and it is this free oxygen alone which is to be considered as entering into the liberation within the body of the sun's heat and energy stored in the food.

This free oxygen exists all over the surface of the earth in a mixture, not a chemical combination, with free nitrogen and several other gases. So far as we know at present, none of these gases when present in the ordinary proportions in the air are used by the body or have any effect, other than purely physical, upon the body, except the oxygen. The air-mixture at the earth's surface and for some miles up has the proportions of approximately 20 parts of oxygen, 80 parts of nitrogen, one part of argon, and traces of hydrogen, neon, zenon, etc., together with approximately 4/100 of a part of carbon dioxid. The latter, which is in this amount as neutral toward the body as is the nitrogen, is nevertheless indirectly as important as the oxygen, since it is from this carbon dioxid that plants build up their fats, carbohydrates, and proteins. Without the oxygen, it would be impossible to oxidize the foodstuffs, but without the carbon dioxid there would be no foodstuffs to oxidize.

Whence come these atmospheric gases? How is it that so active a gas as oxygen, so ready to combine with almost every other element, has not long since entered into such combinations, and so disappeared as a free element from the globe? The same question applies to hydrogen; and to a less extent to the less active carbon dioxid. The remaining gases, including nitrogen, are far less active, far less ready to enter into combination, than any one of the first three, and it is therefore less surprising to find them in a free state.

The probable answer, so far as oxygen is concerned, is that the original sphere of hot gas from which our present

earth was formed by cooling contained such an excess of oxygen that not all of it could find other elements with which to combine, leaving a large amount free. At that time neither plant nor animal existed. The oxygen actually present in our atmosphere now probably has been in combination, most of it many times, in the form of plant and animal substance, and has been set free many times from these combinations by the dislocating force of chlorophyll, acting upon the discarded oxidized "wastes" of the body. Hydrogen we may suppose to have a somewhat similar history. Carbon dioxid is held to have been thrown into the atmosphere from the innumerable volcanoes of the earlier and more strenuous days when the earth was young and hot. It is slowly returning to combinations with minerals now, and is therefore slowly diminishing in amount as a free gas in the atmosphere. Perhaps it was while it existed in the air in greater percentages than at present that the golden age of plants, the carboniferous, held good, and laid down the coal beds we are now using. Experiments appear to have shown that plants supplied with carbon dioxid in excess of the usual present percentage grow to a much greater size than usual. However this may be, it probably is true that the carbon dioxid of today has, like the oxygen of today, a long history of temporary sojournings in plant and animal bodies since the days when it left the volcanoes first.

Of the nitrogen of the air as of the phosphorus and sulphur of the soil a much larger proportion than in the cases of the gases already discussed may not have passed through plant or animal yet.

Mechanics of Respiration

As the body, through teeth, tongue, throat, and esophagus, mechanically carries suitable portions of food to a cavity of the body (stomach and intestines) equipped to so deal with them as to prepare them and absorb them for

cell use, so the body, through the nose, windpipe, chest muscles, and diaphragm mechanically introduces suitable portions of the atmosphere into another cavity of the body (the lungs) where it is prepared and whence it is absorbed for cell use.

Foodstuffs being solids or liquids, having more or less definite physical forms, and being found at a more or less great distance from the body, require the mechanical processes of lifting, carrying, pushing, pulling, etc., to get them to the mouth, and similar mechanical processes within the mouth, processes of pushing, turning, lifting, lowering, to get them to the stomach.

Oxygen, in sharp contrast to food, is a gas, and surrounds the body intimately at every point under a pressure which tends to make it seek entry at every point. Were it not for the impervious skin, the atmospheric oxygen would act directly upon the blood and through it upon the tissues, as indeed it may be seen to do when the color of a recently skinned animal changes from dark red to bright red as the oxygen acts upon the blood. All the orifices of the body, even the lungs, are provided with means of closing themselves; and these close out the oxygen while they close in the materials which the body desires to retain; and, except in the lungs, the exclusion is constant throughout life.

In Lower Animals. The single-celled ameba obtains free oxygen by osmosis from the surrounding water just as it obtains its food. If for any reason the surrounding water is without oxygen, the ameba dies, smothers from lack of free oxygen, just as it would die of starvation if the water contained no food. The ameba takes in oxygen at any part of its surface, just as freely as it takes in any other desirable substance held in solution in the water.

The fish takes oxygen into its body by osmosis, as does the ameba, but not at every point of its surface. Most of the surface of the fish is as impervious to oxygen

as is the surface of the human body. The gill clefts, however, permit the water in which the fish floats to pass directly to the gills which are, simply speaking, portions of the fish where the capillaries in great profusion lie almost on the surface, separated from the water by only a thin membrane through which osmosis readily takes place. If free oxygen is present dissolved in the water, the fish, by means of its gills, appropriates the oxygen as needed; if the water lacks free oxygen, the fish smothers as truly as a man would in an atmosphere deprived of oxygen.

The Lungs in the Human. We may visualize the relationship of a man's lung to the remainder of the body by imagining a portion only of the surface of his body to be impervious to oxygen, and another, say a circular area, to be constituted, like a fish's gills, of an exceedingly thin membrane overlying a great number of capillaries. So long as such an area were well coated with a film of moisture to gather oxygen by solution from the air and so pass it on to the underlying capillaries by osmosis, so long would the body cells beyond receive at least some of the oxygen that they crave. But such an area, so placed, would have certain insuperable disadvantages. Unless provided with a constant flow of water over it, as in the eye, it would be continually in danger of becoming dry. At once osmosis, of course, would cease and the body would smother. Furthermore, the necessarily thin and delicate overlying membrane in this exposed position would be liable to every form of mechanical and chemical injury. Moreover, the entire surface of the human body would not be sufficient absorptive area to take in all the oxygen required. On account of the small size of the ameba, the surface of its body bears an enormously greater proportion to its cubic contents than is the case in man, so that in the ameba the surface area of the cell, which is its body, is sufficient; but man needs a lung surface more than fifty times the area of the body surface or skin. The

skin surface is 1½ sq. meters; the lung surface is 90 sq. meters.

If now, we imagine this hypothetical small, flat, circular, external area of lung surface to be pushed gently inward as one might indent the surface of a rather loosely inflated toy balloon with one's finger, and if we further imagine the process of indentation to be continued until the lung surface has completely vanished from the surface of the body and communicates with it only by a narrow passage; and if we imagine the lung area vastly increased by a great wrinkling of the membrane back and forth, forming a vast number of little cavities (air cells) but each still lined by the membrane and still communicating through the narrow opening with the outside, we may see that this expedient of indentation has effected the protection of the lung surface from drying and from mechanical and chemical injury, and has provided a much greater lung area; but all this at the sacrifice of removing the absorptive area from free exposure to oxygen. The oxygen may still reach the membrane, it is true, but only by the slow process of diffusion through the narrow opening into the small spaces (air cells) between the much folded wrinkles.

If now we force the walls of this indented cavity wide apart, the air, which is under heavy pressure, will of necessity flow in and fill it. The absorptive surface will thus come into direct contact with the air, as if it were still on the surface of the body; and solution of the oxygen in the moisture of the membrane surface, followed by osmosis into the underlying capillaries, may proceed admirably. When this first lot of oxygen is exhausted, however, the walls of our lung must be made to collapse, to empty it so that it may be filled again with new air from which the oxygen has not yet been abstracted. In effect, though with great elaboration of detail, this "indented surface" principle is followed in the human lung (as indeed it is in the human intestine also), with the result that in both

the absorptive surface is moist, protected, and extensive in a small compass.

Among the elaborated details two are of particular interest. One is the lining of the tube (windpipe or trachea) leading from the outside world to the lung. This lining consists of cells possessed of great numbers of fine, short, hairlike processes (cilia) covering their inner free surfaces and therefore projecting into the tube from its walls. One may help oneself to visualize this tube by imagining a tube made of velvet cloth with the "pile" inside, the pile representing the cilia of the windpipe. These cilia are kept in more or less constant motion by the cells especially when any foreign substance, like dust, or any excessive secretion from the absorptive area of the lung lies upon them. The cells do not act irregularly and independently of each other, but coöperatively and coördinately in such a manner that the sum total effect is to send waves of a bending motion over the close-set cilia so that when viewed through a microscope they appear much like a wheat field over which successive puffs of wind are passing. The motion of the cilia is outward (towards the opening of the trachea) hence they move dust, excessive secretion, and other foreign substances out of the lung. This motion, like osmosis, could not proceed if the cell-lined inner surface of the breathing tube were not moist. If it did not proceed, the lung would be "drowned" in its own moisture.

The other detail relates to the outer surface of the lung. The muscles which pull the lung cavity open to admit the air are not attached to the outer surface of the lung itself but in part go to form the walls of a cavity (the thorax) into which the lungs fit snugly, as the rubber bag used in a football or basketball fits into its leather case when the rubber bag is blown up tight before a game. When the rubber bag of a football is thus inflated, it does not move in relation to its leather covering, but the lungs

move continually as the cavity into which they fit expands and contracts, and therefore a lubricant is needed between their outer surfaces and the inner surface of the thorax. This is provided by what may be compared to a very thin-walled, very flat bag (the pleura), containing a very thin film of water, interposing between the lungs and the thorax wherever they come into contact. The inner side of this pleural bag is attached to the outer surface of the lung, thus forming its outer wall; the outer side of the pleural bag is attached to the inner surface of the thorax and thus forms its inner wall. The two inner surfaces of the pleura are all but in contact, the thin film of watery secretion between them acting as a lubricant so that they may slip a little on each other as the thorax expands and contracts.

The Mechanism of Respiration

It should now be clear that enlargement of the thoracic cavity will act to draw the lung open for the admission of air; while contraction of the thoracic cavity will allow the lung to contract and so expel the air. How are the enlargement and contraction of the thoracic cavity effected? This part of the respiratory process by which the oxygen of the air is finally used for oxidation in our body cells is more or less subject to our direct voluntary control, as other parts of the process, including the osmotic changes and the circulation of the blood, are not; and because breathing is, though but in part, subject to our direct control, it is peculiarly a subdivision of hygiene with which we should be familiar, in order that our exercise of partial control should be intelligent and especially not officious or fussy.

The thoracic cavity into which the lungs so snugly fit is conical and air-tight. Its floor, a thin, broad, wide muscle (the diaphragm), which may be compared to a

sheet of rubber, is firmly attached all round to the lower edge of the thorax and projects into it, thus forming a low cone itself within the higher cone of the thorax. When the diaphragm contracts it naturally flattens somewhat; *i.e.,* its cone is lowered, and the cavity of the thorax is thus vertically increased. Men tend to breathe chiefly by use of the diaphragm, but women and children—and men when undergoing unusual exertion—enlarge the thoracic cavity in a horizontal direction also. This is done by the external intercostals, a set of muscles running from the lower edge of each rib to the upper edge of the rib below. At first sight it might appear that contraction of these muscles would draw the ribs more closely together and lessen the thoracic cone vertically instead of increasing it horizontally. However, the combined action of all these muscles does not draw the ribs closer together but raises them somewhat as a result of the anatomical relations of the ribs. Thus, each rib at its dorsal end is firmly hinged to the spinal column. Hence, the dorsal ends cannot be brought closer to nor moved farther from each other. The front ends of the ribs are also most of them attached firmly to the breastbone. These ends also cannot be brought closer to or moved farther from each other. Between these two points of attachment each rib runs somewhat like the half of a barrel hoop around one half of the thorax, its mate on the other side forming the other half. The barrel hoops thus formed do not stand out from the spine at right angles to it, but slant downward and forward from it, each "hoop" making with the spine an obtuse angle above and consequently an acute angle below. It is evident that if the breast bone be raised vertically to bring the "hoop" more nearly to a position at right angles with the spine, the "hoops" will actually be farther apart than they were when they slanted downward. This fact may be perfectly illustrated by raising and lowering the slats of an ordinary window shutter. The slats are farthest

apart when at right angles to their connecting strip, and actually touch each other when the angle is made sufficiently acute (or obtuse). Moreover, when the "hoops" are in a nearly horizontal position, their front ends, attached to the breastbone, are farther from the spine than they are when they are in a more slanting position.

In the body, it is not so much by raising the breastbone that the ribs are brought to a position more nearly at right angles with the spine, but rather by the contraction of the external intercostal muscles which run downward and forward from one rib to the next below it. If these muscles ran at right angles from one rib to the next, they could not contract without bringing the ribs closer together; but since they run downward *and forward,* each single fiber which is attached by its upper end to a point on the lower edge of a rib, will be attached at its lower end to the upper edge of the rib below *at a point considerably farther to the front* than is the point of attachment to the upper rib. In other words, the point of its attachment to the lower rib is further forward from the dorsal hinge of that rib than the point of its attachment to the upper rib is from the dorsal hinge of the upper rib. If a muscle fiber contracts, it necessarily brings its points of attachment nearer together; if they were immovable, it could not contract.

Two such points as described can be brought closer together only by the ribs becoming more nearly at right angles to the spine, that is, by rising from their slanting position. Therefore the contraction of the external intercostals raises the ribs, moves them apart from each other, and increases the diameter of the thoracic cavity from back to front. Since the ribs increase in length to the seventh rib, as we count downward from the first, the increase in the diameter of the thorax is greater in its lower part than in its upper and carries the lower end of the breastbone farther forward than it does its upper end.

These same movements increase the thoracic diameter

from side to side also. If we look at the thorax from one side instead of from the front, we shall see that a rib does not, like a barrel hoop, have its curve all in one plane. If a barrel hoop be placed about the body so that it rests against the spine and slants downward parallel with the dorsal part of a pair of ribs, the parallelism continues only for a short distance, because the ribs slant upward again and meet the breastbone at a point considerably above the hoop. Thus, from both its points of attachment at spine and breastbone each rib slants downward, the front half of the ribs backward, the back half forward, until both halves meet at the side of the thorax at a point below the line connecting the attachments to spine and breastbone. Therefore the external intercostals by raising and separating the ribs from each other increase the diameter of the thorax from side to side, as well as from front to back.

The muscles employed in the contraction of the thoracic cavity are known as the internal intercostals. These muscles, like the external intercostals, extend from rib to rib, but with a reverse slant, that is, downward and backward instead of downward and forward. When the ribs are raised and well apart as a result of external intercostal contraction, the succeeding contraction of the internal intercostals, because of the reverse angle which they maintain with the ribs, reverses the movement of the ribs, drawing them down, narrowing the space between them vertically, and reducing both the front to back and side to side diameters of the thorax.

A number of other muscles running from the spine to the ribs and from the head to the collar bone enter into the breathing movements, some of them in ordinary breathing, some of them only when extraordinary efforts at breathing are made. These muscles are also under voluntary control in ordinary breathing.

The outer wall of the lung held firmly by atmospheric

pressure to the inner wall of the thorax, with nothing between the two walls except the film of moisture contained in the pleura, cannot but follow the movements of the thoracic walls and therefore expands and contracts its cubic content in consonance with the expansion and contraction of the thoracic cavity, thereby securing the required ebb and flow of air into the air cells.

The Breathing Movements

Respiration properly includes all the processes by which oxygen reaches the lungs, is used there, and is thrown out again as carbon dioxid. It is customary nevertheless to use the term in a restricted sense to indicate one complete cycle of respiratory movements, say from a state of "full" lungs through a stage of contraction followed by a stage of expansion until the lungs are "full" again; or from a state of "empty" lungs, through stages of expansion and contraction until the lungs are empty again. The expansion stage is known as inspiration, and the contraction stage as expiration although strictly speaking they should be known as the inspiratory movement and the expiratory movement stages respectively, the term inspiration properly signifying the whole process of getting free oxygen (O_2) to the cell, and the term expiration meaning the whole process of getting combined oxygen (CO_2) out again.

Inspiration, the result of the muscular movements which enlarge the thoracic cavity, is an active movement in all types of breathing, and is due to muscles which are ordinarily under control of the will (voluntary muscles); but it is usually conducted without conscious thought, through practically automatic channels, and in response to the effect upon a sensitive brain center connected with those muscles by nerves, of the presence of an excess of carbon dioxid in the blood as it flows from the cells. It is not,

therefore, *a demand for oxygen* which sets up inspiratory movements, but *a desire to be rid of carbon dioxid.*

Expiration, on the other hand, although the result of the muscular movements which contract the thoracic cavity when special efforts at breathing are made, is a passive movement in ordinary breathing, due not so much to active muscular contraction as to recovery of normal elastic tension by the tissues, including lung membranes, which are stretched by inspiration.

The cycle of ordinary breathing, therefore, consists of a relatively slow inspiration due to muscular effort, an almost imperceptible pause at the height of expansion, a relatively quick passive expiration, and a fairly definite pause before inspiration follows. In deep or forced breathing, the passive resiliency which is sufficient to secure expiration in ordinary breathing is reinforced by muscular contractions which, like those of inspiration, are usually automatic and unconscious but may be instigated at will.

The Lung Capacity

The actual amount of inflow and outflow of air accomplished by these movements depends of course on the size of the thorax and the extent of the movements, provided there be no obstruction to the free passage of the air. In strangling (due to obstruction of the trachea, say) terrific movements, even convulsive, of the respiratory muscles are made, but of course without movement of the air either into or out of the lungs. For convenience, one speaks of filling and emptying the lungs in respiration, but in ordinary life, one inspiration seldom fills the lung to capacity, and no amount of expiration ever completely empties it.

Tidal Air. Filled to capacity, the average adult lung may contain about nine pints of air; ordinarily, however, it does not, even at the height of ordinary expansion, contain more than six pints. At the end of ordinary expira-

tion, the lung still contains about five pints, and the succeeding inspiration merely restores the one pint lost. This one pint, taken in and thrown out in ordinary respiration, is known as the ordinary tidal air. The formula for the fluctuating content of the lungs in pints in ordinary inspiration is therefore 5-6-5-6-5-6-, etc.

Residual, Complemental, and Supplemental Air. When emptied to the greatest degree possible by extraordinary efforts at expiration, the lung still contains about two pints of air (residual air). To return to the content usually present at the end of an ordinary expiration three pints must be added; these three pints are known as complemental air. By extraordinary efforts at inspiration to the greatest degree possible, the lungs may be made to contain nine pints. To return to the content usually present after an ordinary inspiration three pints must be expelled; these three pints are known as supplemental air. Hence the formula for deep or forced breathing would be 2-9-2-9-2-9-, etc., with an unusual tidal air, therefore, of seven pints, made up of the tidal air of ordinary breathing plus the complemental air plus the supplemental air. Under various circumstances, especially with various amounts of exercise, the formulæ representing the alternate expansions and contractions of the lungs will vary in many combinations, between the 5-6-5-6-5-6 of quiet breathing and the 2-9-2-9-2-9 of forced deep breathing, but always, except in the extreme stages of strangulation, the formula of the moment is a measure of the carbon dioxid accumulation in the blood, with the exception of such aberrant forms of breathing as sighing with sadness, gasping with surprise, sneezing, laughing, which are probably, at least in some cases, psychic reflexes.

In young infants the lungs empty themselves in expiration much more nearly than in older children or adults; but once a baby has drawn a single breath and has thus legally distinguished itself from a still-born child, no part

of its lungs ever again becomes quite free from air, except as a result of advanced disease. All that has been said so far applied to the lung in a closed thoracic cavity. When a lung is removed from its thoracic cavity, it collapses relatively, losing even its residual two pints very largely. But in this general collapse a stage is reached, before the air cells are quite empty, when the smallest bronchioles collapse and thus trap a quantity of air which, though minute, is nevertheless sufficient to ensure that the lung tissue will float on water. This air is known as minimal air. Even a very small fragment of a lung which has once been expanded will usually float.

Air-Passage Air. The influx of air provided by the 5-6-5-6 formula of quiet breathing, about one pint, or say 500 c.c., does not by any means all reach the air cells at once. The five pints already present at the beginning of an inspiration occupy the space from the nostrils to the air cells inclusive. Of these five pints, a little less than a third of a pint (*140 c.c.*) *occupies the nares, throat, trachea, bronchi, and bronchioles,* which are non-absorptive of oxygen, and practically do not change in capacity with the breathing movements. Thus the amount of air actually in the air cells is about four and two-thirds pints.

When now a pint of new air is drawn in, we may visualize it as carrying before it, on entering the nostrils, the old air already in the nares, throat, trachea, etc., which latter air is therefore the first to enter the expanding air cells. Evidently the first 140 c.c. of the expansion of the lungs due to this inspiration must occur before the new air has passed deep enough into the air passages to reach the openings of the air cells; we are for the moment disregarding the diffusion which occurs between the new air and the old where they come in contact wth each other, and also the mixing effect of currents, eddies, and other transferences set up by the movements themselves. If the inspiration should cease at this point (*i.e.,* when only

140 c.c., of expansion has occurred), its only effect so far would be to transfer the air in the air passages to the air cells, and fill the air passages but not the air cells, with new air from outside the body. An expiration of 140 c.c. at this point would merely drive to the outside atmosphere the new air in the air passages, refilling the latter with old air from the air cells. If, however, the inspiration is completed as usual to the extent of 500 c.c. total, 360 c.c. more of new air will enter at the nostrils and thus make up the pint of tidal air.

If then we disregard diffusion and mixing alluded to above, we may visualize the inhalation of 500 c.c. entering at the nose as driving before it the 140 c.c. already in the air passages, and following it into the air cells to the extent of 360 c.c. of new air at the end of the inspiration, leaving the remaining 140 c.c. of new air to fill the air passages. Thus in all, 360 c.c. of new air have entered the air cells where they have mixed with 140 c.c. of old air present in the air passages at the beginning of the inspiration, and with the five pints, approximately, of old air (complemental plus residual) which were actually in the air cells at the same time. This air-cell air we may consider as representing the condition of the air in the lungs after it has been exposed to the usual depletion of oxygen and loading with carbon dioxid. The new air we may consider as having the ordinary composition of the outside atmosphere.

But how shall we rate the air-passage air? To properly appraise it we must consider what happens in expiration. The thorax, on beginning the 500 c.c. contraction of ordinary breathing, expels first to the outer atmosphere the 140 c.c. of new air which was left at the height of the preceding inspiration, and filled the passages from the air-cell mouths to the nostrils. Following this air and driving it along, comes the air-cell air, a mixture a moment since of outside air, air-passage air, and air-cell air, but

now all air-cell air. When the expiration ceases, 500 c.c. of this air-cell air will have left the air cells; the first 360 c.c. of it will have passed the nostrils and joined the outside atmosphere; the remaining 140 c.c. will remain to fill the air passages. It would appear obvious then that this air-passage air, as it is drawn directly into the lungs at the beginning of the next inspiration, is nothing more than air-cell air left in those passages by the last expiration. This is true except in so far as the air-passage air is modified in composition by diffusion with the outside air at the nostrils during the pause between expiration and the next inspiration, and the diffusion and mixing of these two during the inspiration itself. To the extent that it diffuses with the outside air through the nostrils during the pause, it is improved; but the subsequent mixture and diffusion during the process of inspiration, while it improves the air-passage air, impairs the new air and may therefore be disregarded. Hence we may take it, that the air-passage air is not very different in composition from air-cell air. Therefore, in an ordinary inspiration, only 360 c.c. of really new outside air actually reaches the air cells and becomes available for absorption.

This means that the average air cell in ordinary respiration has presented to it for its purposes, new outside "fresh" air in the proportion to old air of about *one-seventh* (360 c.c. to 2500 c.c. + 140 c.c.) indicating that it takes at least *seven or eight ordinary respirations* to change the air in the lungs completely, and that at all times during the ordinary respiration, the air cells are quite content with air of which not more than one-seventh was derived from the seventh preceding inspiration, one-seventh from the sixth preceding inspiration, one-seventh from the fifth preceding inspiration, and so on; only the last one-seventh being derived from the last inspiration, and therefore only this one-seventh being actually fresh from the outside world.

In the formula for forced or deep inspiration, 2-9-2-9, the situation is very different and the air cell is presented at the end of each inspiration with air of which about seven ninths is from the outside world, which indicates a complete change of air in the air cells approximately seven times during nine respirations. This does not mean, however, that the actual percentage composition of the air in the air cell is greatly different from the percentage composition which obtains during quiet breathing, but merely that the depletion of oxygen and loading with carbon dioxid proceeds much faster. This is especially true when the deep respirations are the result of exercise or of other natural demands of the body. When deep respiration is carried on by the will without any body demand for it, the situation developed is an over-oxidation and a depletion in carbon dioxid which requires a subsequent period of shallow or even of no breathing to compensate for it and restore the normal balance. Such excessive breathing sometimes results in tetany.

Summary

The term respiration, broadly interpreted, covers that part of the subject of nutrition which deals with the introduction and use of free oxygen, and with its elimination after it has been used in the form of carbon dioxid. As the introduction of foodstuffs provides the fuel, so the introduction of free oxygen provides for the burning of the fuel. Neither food (oxidizable material) nor free oxygen is of use to the body cells unless both are present together.

Although much oxygen is introduced into the body in chemical combination, forming important parts of the proteins, fats, carbohydrates, salts, and water of the food intake, such oxygen is not available for oxidation of the foodstuffs, but represents a certain degree of oxidation which has already gone on before the foodstuffs enter the

body at all. It would appear that one essential feature of all foodstuffs is that the foodstuffs shall have undergone such a partial oxidation before presentation to the body for its uses. Certainly it is true that none of the ordinary foodstuffs are in a state of complete de-oxidation, although they would then be of higher potential value as sources of heat and energy.

Oxygen, constituting about one-fifth of the all pervading atmosphere at the surface of the earth, surrounds the body and enters the body under its own pressure. In health the body restricts the entry of oxygen to one cavity only, the lungs, and ensures its entrance thereto by expansion of the cavity walls; by the contraction of these walls, it later drives out the used oxygen, now in the form of carbon dioxid. The cavity is lined by a thin moist membrane, immediately underlying which is a rich profusion of capillaries; thus the cavity is provided with the necessary mechanism for the operation of osmosis of oxygen (through the membrane) to the blood.

The respiratory movements in ordinary breathing do not introduce pure oxygen into the lung. They introduce atmospheric oxygen, which is oxygen mixed with about four times its bulk of other gases, none of which are useful to the lung, so far as we know, except as they dilute the oxygen. In ordinary respiration, even this mixture is not so introduced as to replace at each breath the whole amount of air previously present, but in installments so small in proportion to the lung content of air that about seven to eight breaths must be taken to accomplish a complete change of air, while at no stage is the proportion in the air cells of new to old air greater than one to seven.

In deep or forced respiration, the air is changed at a rate which may be as high as seven changes in nine breaths, the proportion in the air cell of new air to old rising as high as seven parts in nine. When deep respirations occur as the result of unusual need in the body for oxygen or

for elimination of carbon dioxid, the percentage composition of the air-cell air is not enriched in oxygen or lowered in carbon dioxid; but the resultant more rapid ebb and flow ensures a larger supply of oxygen and a larger elimination of carbon dioxid in a given time. When deep respirations are made by mere exercise of the will, without any real demand from the tissues, the excessive supply of oxygen and, to a greater extent, the excessive elimination of carbon dioxide, produce a situation demanding a period of lessened respiration or even of cessation of respiration to counterbalance the unnecessary excesses. Serious consequences (tetany) are sometimes produced if deep respirations, uncalled for by the body, are long continued.

CHAPTER VIII

CIRCULATION OF OXYGEN IN THE BODY

Oxygen as it reaches the air-cell (alveolus) of the lung requires no change of form or digestion, as does food, to make it soluble, for as a gas it is already soluble and therefore diffusible.

But the water of the blood which is able to dissolve foodstuffs in sufficient quantity, once digestion has made them soluble, is unable to dissolve oxygen in sufficient quantity, although the oxygen comes in its native soluble form. The body demands about twenty times as much oxygen as the water of the blood could carry to it in watery solution, under the conditions of temperature and pressure which exist in the body. If the blood could be cooled materially or the pressure of the atmosphere were materially higher than it is, the water of the blood could hold more oxygen in solution. But under ordinary conditions, the first would be fatal to the body and the latter impracticable. The latter has been tested experimentally. Conditions of high pressure exist in caissons, and in diving bells, divers' suits, etc., and under these pressures oxygen solution in the blood does increase, although not to the required point.

In the case of foods insoluble in their native states, digestion renders them, by slight changes in chemical constitution, soluble and diffusible. But oxygen as it is presented to the blood already exists in its simplest chemical form and therefore cannot be broken down into more soluble fragments. Also it cannot be built up into a more

soluble form by ordinary chemical combination to advantage, for while this might easily render it soluble (as certainly would be the case if the oxygen were built up into water, or carbon dioxid), yet the compounds so formed would be too stable for the body to later break up. As has already been made abundantly clear, oxygen in combined forms as water, salts, carbohydrates, fats, and proteins are constantly present in the body, but their oxygen is quite unavailable for combustion purposes.

These difficulties in the transportation of oxygen by the blood are met by the use of a substance (hemoglobin), itself insoluble, which is provided in the blood in the form of an iron-containing protein constituent of the red blood corpuscles. The clear, almost colorless, liquid of the blood, holding many things in solution, holds in suspension two varieties of cells, the reds and the whites. The red cells are by far the most abundant, usually averaging about 5,000,000 to the cubic millimeter. These travel in the blood stream at nearly the same speed at which the liquid itself flows, which is great enough to ensure that the average blood cell makes a complete round of the body circulation from the heart to the capillaries and back to the heart again about twice a minute. Of course the red cells travel much faster in the arteries than in the capillaries, and this variation in speed keeps them in the center of the stream in the wide arteries where they are merely travelers hastening to their goal, but allows them to approach the walls of the narrow capillaries, where they are to deliver their burden of oxygen to the body-cells, and where they often travel in single file, as well as relatively slowly.

The little bi-concave discs which are these red cells appear red in bulk (although yellow in thin films) from the presence in them of the hemoglobin, which probably on account of the iron it contains has the property invaluable to the animal world of making with oxygen a very loose physico-chemical compound, involving only negligible heat

evolution on combination or heat absorption on decomposition. Its physico-chemical absorption of oxygen is subject within limits to the degree to which oxygen presses for absorption; so that in the lung where oxygen is abundant and its partial pressure is therefore relatively high, the hemoglobin takes up oxygen readily; in the capillaries where the oxygen is scarce and its partial pressure is therefore relatively low, the hemoglobin parts with oxygen just as readily. Hemoglobin undergoes a change in the depth of its color as its oxygen association changes, being bright red when saturated with oxygen (oxy-hemoglobin), dark red when lacking oxygen (reduced hemoglobin). It is therefore dark red as it goes to the lungs, bright red as it comes away from them; bright red in the arteries on its way to the capillaries, dark red in the veins on its way back from the capillaries.

Amongst the store of facts known to the human race everywhere, none is more commonplace or widespread than the redness of blood and the greenness of vegetation. It is interesting to reflect that it is the green-colored matter of the plant which ultimately furnishes to man the food he needs and that it is the red-colored matter of the animal which ultimately furnishes to man the oxygen which makes it possible for him to use that food. Without the trace of iron (about 6 grammes in an average human adult) which hemoglobin carries, animal life on this planet would almost wholly disappear. Some shellfish, however, are able to use copper instead of iron for the carriage of oxygen, their blood being of a greenish purple.

This addition to the blood of the hemoglobin is obviously, in effect though not in fact, equivalent to increasing the ability of the blood to dissolve oxygen.

Osmosis of Oxygen in the Lung. Hemoglobin may pick up oxygen directly from the atmosphere when exposed to it, but this not the case in the animal body. Between the red cell in the capillaries of the lung and the gaseous

oxygen in the air cell (alveolus) of the lung, there always intervene first the layer of water (of the blood) which surrounds the red cell, then the membrane formed by the capillary wall, then a layer of lymph between the membrane formed by the capillary wall and the wall of the alveolus, then the wall of the alveolus itself, and finally a layer of moisture over the alveolar wall on the atmospheric side. Gases may, it is true, diffuse through a dry membrane, though solids would not, but in the body it is probable that in passing through membranes, gases always travel in solution in water. The passage of oxygen from alveolus to hemoglobin requires the solution of the oxygen in the moist coating of the alveolar wall; its diffusion through the alveolar wall to the lymph; its diffusion through the lymph and then through the capillary wall into the liquid of the blood; from which latter it is taken up by the hemoglobin, forming the bright red hemoglobin known as oxy-hemoglobin.

Pressure an Important Factor. The driving power which sends the oxygen into the hemoglobin would appear to be the partial *pressure* of the oxygen in the alveolus, and not the *pulling power* of the hemoglobin, which latter is too feeble to direct the stream of oxygen toward itself. So long as the partial pressure of the oxygen in the alveolus does not drop too low, the oxygen will flow, under this pressure, from the alveolus to the blood-stream and the hemoglobin takes up the oxygen thus presented to a degree which is slightly under its full capacity. Thereafter, increase in the amount or pressure of the oxygen in the alveolus may add slightly to the amount of oxygen carried in the hemoglobin, and thus saturate it.

Further increase in the oxygen supplied, while increasing somewhat the oxygen *in solution* in the *liquid* of the blood, does not increase the amount taken up by the hemoglobin. It is for this reason that when attempts are made to greatly increase oxidation in the body by supplying to it

air containing an abnormally high percentage of oxygen, even under high pressure, the results have been disappointing. It is true that where the demand for oxygen is very great in proportion to the lung surface available, as in some lung diseases or during very strenuous exertion, an increase in the percentage of oxygen supplied quickly relieves the body of the necessity of making strenuous exertion to obtain the oxygen it needs. Except in such extreme conditions, the amount of oxygen regularly available to the blood is more than sufficient to meet all its demands.

Liberation of Oxygen in the Cells of the Body

The picking up of oxygen at the lung has been described; it remains to consider the somewhat similar processes by which the oxygen is dropped again at the body cell. In the distal capillaries we have almost exactly the converse of the conditions in the lungs. The hemoglobin arrives in these capillaries saturated or nearly so with oxygen. It has no particular urge of its own to part with the oxygen, however. In the alveolus the oxygen being in gaseous form is in active molecular motion, seeking to expand, to dissolve, to diffuse, by any path offering a sufficiently low resistance. In the hemoglobin the oxygen is relatively stable, at least temporarily restrained by its loose combination. If we may consider the reception of the oxygen by the hemoglobin in the lung as rather forced upon the hemoglobin than actively demanded by it, we must also consider the departure of the oxygen from the hemoglobin in the capillary as a yielding up of oxygen by the hemoglobin in response to imperative demands rather than an active throwing off of oxygen as an unwelcome guest. This demand comes from the body cell, which has actively used up its oxygen and greatly requires more. It draws by osmosis on the oxygen in solution in the surrounding lymph. The lymph, thus depleted, seeks by

osmosis to secure its quota by osmosis through the capillary wall from the oxygen in solution in the blood. The depletion of the liquid of the blood creates a demand for oxygen which can be supplied only by the stores held in loose combination by the hemoglobin. We may then visualize the hemoglobin as a rather negative sort of beast of burden, upon whose back the oxygen is thrust in the lungs and from whose back the oxygen is torn in the capillaries. The oxygen is thrust upon it and torn from it by the ordinary rules of solution and osmosis which we have seen so widely operating in the body in the transfer of foodstuffs and of their waste products.

Formation and Carriage of Carbon Dioxid

When free oxygen reaches the cell, it is there promptly used to combine with fats and carbohydrates derived directly from the foodstuffs as such; with the carbohydrate-like non-nitrogenous fragments of the protein foodstuffs, derived directly in like manner; and with fats and carbohydrates derived from the stores of those substances in the body. Insulin, from the pancreas, is in some way essential to the burning of the carbohydrate; and the burning of the latter is an essential to the complete burning of the fat. But the fats and carbohydrates of all descriptions are, we believe, quite simply burned up by combination with the oxygen, just as they would be if they were burned in a big bonfire in the open air. True, they are burned in quite microscopic quantities, and with such prompt detachment and absorption of the heat they generate that they never accumulate enough heat at any one point to raise the highest temperature of the body much above 110 degrees Fahrenheit, a temperature seldom observed without death following promptly. Elaborate mechanisms exist for the regulation and distribution of this heat and for the disposal or excretion of any surplus that might be harmful.

The products of combustion of fats and carbohydrates in the open air are in part carbon dioxid and water, both tasteless, odorless, and invisible; in part, all sorts of gaseous products intermediate between fats and carbohydrates on the one hand, carbon dioxid and water on the other. These we recognize by the peculiar odors of burning and in part some solid, often carbonaceous, compounds, not fully oxidized, which we recognize by sight as smoke. The products of combustion of the same substances at various stages in the body are not unlikely to be similar intermediate products, but they do not escape as such. The body cell consumes its own smoke, so to speak, and reduces all of these intermediate products sooner or later to the common level of carbon dioxid and water. The excretion history of this particular water is hard to follow with any minuteness, for rather obvious reasons, since it quickly becomes lost in the general water-content of the body. The excretion history of the easily identifiable carbon dioxid is, however, well known. Accumulating in the cell in great excess of its concentration in the lymph, the carbon dioxid moves to the lymph through the cell wall. The lymph contains a greater concentration than the blood, so that it continues to move, through the capillary wall, to the blood liquid. Here, if not earlier, some of it finds certain salts of the blood, more or less alkaline, having a loose chemical affinity for carbon dioxid, not unlike but less in degree than that which hemoglobin has for oxygen. Some of it also dissolves in the liquid of the blood. The rest of it enters into a loose combination with the hemoglobin, not, however, with the iron portion as does oxygen, but with the protein portion. It is at present believed that this combination with the protein of the hemoglobin, perhaps also with other proteins of the blood, furnishes to carbon dioxid the chief of its transportation facilities. Reaching the lungs, the blood finds itself surrounded by liquids of lower carbon dioxid content than it carries in solution. At once

the familiar diffusion processes begin, depleting the liquids of the blood through the capillary walls to the lymph. The lymph parts with its carbon dioxid to meet the demands of the alveolar moisture, which in turn gives up its carbon dioxid to the alveolar air. The hemoglobin yields to the demands of the blood stream about it and parts with its charge to make good the depletion the blood stream thus has suffered.

The Alveolar Air

Atmospheric air is usually cooler than the body and therefore, when taken into the lungs, it is warmed, as a rule, because it is quickly brought to the temperature of the body. Atmospheric air is usually not saturated with moisture, but in the lung it quickly becomes saturated. Atmospheric air contains about twenty parts in 100 of oxygen. In the lung it loses about 5 to 6 parts to the blood. Atmospheric air contains about 4/100 of a part in 100 parts of carbon dioxid. In the lung it has added to it somewhat less in carbon dioxid than it loses in oxygen, but varying between the same approximate figures. The nitrogen and other normal gases are little altered by their sojourn in the lung. It is true that nitrogen dissolves to a small extent in the blood, but appears to have no effect whatever upon the body under ordinary conditions. (But see Caisson disease.)

Alveolar air will thus have a composition showing oxygen about 14 to 15 parts, carbon dioxid about 5 to 6 parts and of the rest, nitrogen and water vapor chiefly, about 80 parts in 100 parts (neglecting the other gases, the percentages of which are insignificant at present).

The note made above that the volume of carbon dioxid gained is slightly but definitely less than that of the oxygen lost brings out an interesting relationship. In accordance with the well-established laws of gases, a given

quantity of oxygen, combining wholly with carbon to make dioxid, will yield an amount of carbon dioxid which although weighing exactly as much as the weights of the oxygen and carbon put together will occupy exactly the same volume as the oxygen did alone, under of course the same temperature and pressure. Why then does not the oxygen taken from the lungs reappear in the lungs as an exactly equal volume of carbon dioxid, instead of as a slightly smaller volume? It is evident that the difference in quantity represents oxygen which has not been returned to the lung as carbon dioxid. What then has become of it? Oxygen, in burning the fuels of the body, combines with the very abundant carbon to form carbon dioxid, also with the still more abundant hydrogen to form water. But only the former shows in the alveolar air; the latter is lost in the general water of the body. Four times as many oxygen atoms are required to combine with a given number of carbon atoms as are required to combine with the same number of hydrogen atoms. Moreover, it will be remembered that the foodstuffs of the body are all partially oxidized before they enter the body at all. The probability that this original partial oxidation is an oxidation of the hydrogen rather than of the carbon seems to gain support from the smallness of the difference between the oxygen burned in the later oxidation and the carbon dioxid returned. About one-eighth only of the oxygen fails to reappear. This amount of oxygen would combine with four times as many atoms of hydrogen as of carbon. It would seem then that the oxygen atoms burn up the hydrogen atoms and carbon atoms of the body in the proportion of four of the former to seven of the latter.

Suppose the oxygen taken in = 48 atoms and that the amount recovered as CO_2 = 42 atoms, which is 7/8 of the whole.

Then if the remainder combine with H, 6 atoms O require 12 atoms H = 6 H_2O.

Hence the original 48 atoms O combine with 12 H and 21 C, which is in the proportion of 4 H to 7 C.

However this may be, the point is very clear that the human lungs find quite sufficient to their needs an alveolar atmosphere which presents a composition far worse from the standpoints of deficiency in oxygen and excess of carbon dioxid than the usual standards for "pure air."

Control of Respiratory Movements

We divide the muscles of the body into two groups, voluntary and involuntary, the former containing such muscles as those of the arm and leg which we can contract or relax at pleasure; the latter containing the muscles of the intestinal wall, of the arterial walls, and many others, over the contractions and expansions of which we have no control. Indeed, we seldom are aware from any sensation set up that such contractions occur at all.

This boasted control of the voluntary muscles is, however, far from complete, and is continually being taken from us and exercised by the automatic mechanisms of the body for its own purposes. The really important muscular movements of the body, measuring their importance by their contributions to the continuance of life, are those of the heart, and of the arterial walls, which keep the circulation moving; of the intestines, which keep the food supply moving; and of the lungs, which keep the oxygen supply and excretion moving. The first and second of these remain in the firm grasp of the automatic control of the body; the third only has been partially entrusted to the will. It is as if Nature, through the experience of eons, in building bodies which carried but a modicum of brain attached, had learned to make the body processes as foolproof as she could, and to trust the conscious oversight of the body and its operations to the brain very reluctantly, lest ignorance and neglect should end them before they

were well begun. In its long slow development, the brain has become, in the human of today, a sort of Frankenstein's monster, the wilful encroachments of which on Nature's beautiful automatisms may be regarded with a good deal of dismay. Bit by bit the brain has attempted to take over more and more the direction, conscious and purposeful, of body movements, which are body functions. What else is Modern Hygiene but an attempt to direct consciously that which in old times Nature alone conducted?

So far Nature, fortunately for us, has managed to retain in her own grasp most of the more vitally important movements, these internal movements that keep the mechanism going, leaving to the brain the less important external movements, that chiefly operate to produce mere changes of position. Even in these, however, Nature has not handed over complete control. In the presence of emergencies, she snatches the reins from the slow, careless, negligent, and dreamy brain, handing them swiftly back to her old reliable and all but perfect automatic mechanisms. Thus, Nature allows you to control your own eyelids when nothing much is happening, as a mother lets her baby toddle in the yard, where it can hardly hurt itself much. But if a spark, an insect, or a sand-grain should fly too close to your most precious eye, your eyelid closes long before you know anything about it. Just so the mother snatches up her child and runs to safety with it long before it even sees the prowling dog or snake. Even the muscles of the leg and arm and hand, our most controllable muscles, are controllable only within a limited field. If danger threatens, we "dodge before we know it"—the oldest soldier ducks to the bullet's hum without intending to—often against the strongest efforts of his will.

Crossing a narrow foot-plank over a mountain gorge may be a task too much for a conscious managing brain to attempt, and may end in disaster if the assuming brain

attempts the delicate movements. But set the brain aside as in the sleepwalker, or distract its attention as in the fleeing goat, and then Nature's automatisms convey the body over without a quiver.

This "snatching of the reins" from the will is nowhere more definitely in evidence than it is in the movements of respiration. True, both the diaphragm and the chest muscles of respiration are "voluntary muscles," and we can suspend our breathing, make it deep or shallow, slow or rapid, as we please—so long as these changes do not make much difference to the body operations. But if we "hold our breath" long enough to threaten danger to the body, the stimulation of the respiratory center in the brain becomes stronger than any determination of the "higher" centers can meet, and a deep breath is taken. At least the attempt at a deep breath is made, even though, as in hanging, the attempt is futile, because of the constricting rope; or is disastrous as in drowning, where it floods the lungs with water. The real function of the brain is not to operate or direct the general conduct of the body in ordinary life, but to prevent the body from becoming exposed to such extreme conditions as hanging or drowning, conditions beyond the power of the body to meet at all. One other great function that the higher brain may carry out is a conscious development by exercise of the automatisms of the body against the day when they may be needed in greater range of adjustability than they had as they were first bestowed upon the body. Thus "by practice" one may learn to hold one's breath for gradually longer and longer periods, and on occasion some day one may be able to hold it the few seconds longer that may make the difference between drowning and escape from drowning. Another is the "invention," so to speak, of new automatisms, of the external movements, chiefly, which, at first developed under the direction of the brain, as in writing or swimming, can in time be handed over to the automatic centers almost

entirely. There seem to be authentic instances of individuals who have "learned" to invade even the natural automatisms of the body so as to control by will power alone the rate of their heartbeats or the movements of the intestines. But for most of these internal movements our control is indirect, and is achieved only by such external movements as will change the conditions of the body to the point where automatic changes are brought about to meet the changed conditions. Thus we cannot by "taking thought" change the color of the skin, but by exposing it to the sun we may induce it to meet the unusual situation by itself changing its routine and making for itself a pigment, resulting in "tan" or freckles. We cannot by taking thought increase the strength or size of the heart, but by calling on it to use its own present powers through exercise, we may gradually increase both very materially. So also with the lungs—use is the great developer of function.

The danger of developments proposed by or induced unconsciously by the higher brain are, first, that they may not be needed by the body as a whole; and second, that they may be developed at too great a rate to ensure the correlative changes in the body keeping up with them.

Voluntary forced breathing, the body being otherwise at rest, with a view to oxygenating the lungs, sweeping out accumulated impurities, changing and refreshing the body air, is often advocated as a "hygienic" measure. But in the light of the foregoing outlines of the exquisite adaptations of the body functions to the body needs, it seems rather evident that this artificial forced breathing is an excellent example of zeal without knowledge. The effect is doubtless to introduce into the lungs a greater amount of oxygen in a given time than ordinary. Since, however, the body cells are using this oxygen at the old rate, and except as the forced movements of the deeper respirations require a slightly greater metab-

olism in the muscles involved, do not desire and cannot use this extra oxygen, there would be no object gained in furnishing it to them, any more than there would be in opening the draught of a furnace which was already fully supplying all the heat and energy needed at the moment. Moreover, it is quite unlikely that such forced respiration, not accompanied by the corresponding increase in rapidity of the circulation which is an inevitable accompaniment of the deeper respiration induced by exercise, will carry the increased oxygen away from the lungs at all. If the blood does carry it away in proportion to its increased intake, as it does in exercise, then certainly no increase in the stock of oxygen in the lungs is achieved. If it is increased because the blood cannot carry it away fast enough, what has been gained? At most, the increased oxygen in the lung will mean a slightly greater solution of the oxygen in the liquid of the blood, and therefore a slightly larger charge of oxygen in the hemoglobin. Hemoglobin as it comes from the lungs is saturated to about 19/20 of its capacity, *i.e.,* it carries 19 c.c. of oxygen per 100 c.c. of blood, where it might be forced to carry 20 c.c. Hemoglobin as it passes through the distal capillaries parts with about 7 of the 19 c.c., under the ordinary conditions of the body. If in will-forced artificial respiration, this extra possible 1 c.c. be carried to the capillaries (of which there is no proof), if it is there absorbed and burned (of which there is no proof), it has merely created *more* and *unrequired* heat to be eliminated, more carbon dioxid to be carried away. What, then, has been gained?

On the other hand, will-forced respiration does accomplish a greater elimination of carbon dioxid from the lungs. This means a lower percentage in the alveoli and therefore an increased flow of carbon dioxid from the blood to the alveolus. This means a lower percentage of carbon dioxid in the circulating blood, and a

corresponding lack of the ordinary normal stimulation of the respiratory center. Hence the moment the self-forced respiration ceases, the normal automatic breathing stops for a time, to allow a sufficient accumulation of carbon dioxid in the blood to demand another respiration of the respiratory center.

Note now that this evident diminution in the carbon dioxid of the blood, thus demonstrated, in will-forced respiration, means that the increased oxidation of the tissues which we discussed above as a hypothetically possible result of the hypothetical increase in absorption of the oxygen by the hemoglobin evidently does not occur. If will-forced respiration did increase oxidation, the carbon dioxid would necessarily be increased also, and the automatic center in the brain would suffer no abrupt cessation of the carbon dioxid stimulation under which it normally acts.

Contrast this with the body-forced respirations of exercise. In the first place, there is a strict gradation of the increased respiration to the demand of the body for increased heat and energy required for the increased movements. A small amount of increased metabolism calls for a small amount of increase in oxygen, and elimination of carbon dioxid. A large increase in exercise calls for a large increase in oxygen supply and a corresponding increase in carbon dioxid elimination. In will-forced respiration there is a very great increase in oxygen supply to and in carbon dioxid elimination from the lungs with no demand whatever for either from the body, except such as the increased action of the respiratory muscles themselves may make.

In the body-forced respiration of exercise, the circulation is speeded up also *in exact proportion* to the needs of the body, and thus provides for the more rapid exchanges of oxygen and carbon dioxid in the lungs and in the tissues. In will-forced respiration the circulation

is not speeded up *in proportion* to the oxygen intake and carbon output of the lungs, but only to the extent demanded by the increased metabolism due to the increased respiratory movements. Here is a very definite dislocation of the fine automatic adjustments of the body, rather comparable to attempting to force increased gasoline and air on an automobile engine without providing a sufficiently large tube to carry them to the cylinders. Finally, the body-forced respiration of exercise provides for the increase in heat production by increase in the processes concerned in the elimination of the heat, notably by an increase in perspiration. The fact that the increased perspiration of will-forced respiration is not proportionate to the increase in oxygen introduced into the lungs, but to the increased metabolism due to the respiratory movements themselves, still further confirms the view that will-forced respiration does not really increase the general metabolism of the tissues, even while it is going on; for the cessation of breathing following for a time the cessation of the will-forced respiration indicates that the latter has not initiated an increased metabolism, which would show itself by continued deep respirations, not by cessation of respiration!

We may sum up the subject of self-forced respiration with the conclusion that it is the chief if not the only example which can be adduced of the body being compelled to accept more oxygen and forced to eliminate more carbon dioxid, than suits its needs. No other form of exercise, except perhaps swimming under water, but carries with it compensating adjustments to provide oxygen and eliminate carbon dioxid in the proportions demanded by the body metabolism. In swimming under water, the converse conditions are imposed on the body, for increased metabolism is induced with absolute cessation of oxygen intake, or carbon dioxid elimination, so far as the lungs are concerned. It is true that the diver may allow an

escape of his lung air under water, and so rid himself of a modicum of carbon dioxid, but since the lung collapses in like proportion, the percentage of carbon dioxid is unaltered.

The second great danger to be avoided in the very laudable pursuit of developing the body automatisms to a wider range, that of attempting to develop them too rapidly, is a very real danger, peculiarly likely to materialize. A short-winded man proposes to overcome his short-windedness by exercise. Usually he neglects to discover whether or not his short-windedness is merely, as he assumes, "lack of practice," or is in fact due to disease. But if he is free of disease and really needs exercise, nevertheless he is almost certain to take it too abruptly and too violently, imagining that what he has to overcome is some sort of psychic inertia of his body, requiring chiefly a vigorous mental effort, devoted to driving his body on willy-nilly, rather than an actual deficiency in muscle, nerve-training, coördination of heart and circulation with lung and intestine, and many other delicate intricacies. It is too often the impatient higher brain desiring immediate results that is at fault, rather than the body, when impetuous exercise in those not made ready for it by easy gradations ends in disaster. The would-be athlete too often regards the development of the muscles of leg and arm of the chief consequence, forgetting that heart and lung and stomach are absolutely first, the limb development quite secondary, all but incidental.

Summary

Oxygen as oxygen is supplied to the body-cell from the lung, and is eliminated as carbon dioxid from the body-cell to the lung by methods quite similar in principle to those employed in carrying food to the body-cell from the intestine, and in eliminating the body-cell waste.

The details, however, differ materially, and particularly in the processes of preparation for absorption.

The initial introduction of free oxygen to the body, an all-surrounding, all-pervading gas, is accomplished through the formation of a potential vacuum in the lungs by the enlargement of the thoracic cavity into which the lungs fit snugly; and the resulting inflow of atmospheric air, of which about 20 per cent is the desired oxygen. Very partially through its solubility in the watery portion of the blood, chiefly through its loose chemical affinity for the iron which forms part of the hemoglobin of the red blood cell, the oxygen under the pressure which it has in the lung is taken up by the blood coming to the lung from the tissues, because the pressure of the oxygen in this blood is less than it is in the alveolus. The oxygen, thus thrust upon the hemoglobin, is swept with the hemoglobin to the tissues. There the activities of the cells continually convert free oxygen into carbon dioxid, and thus keep the oxygen pressure of their immediate surroundings at a relatively low ebb. The loaded hemoglobin, entering this area of low supply, has its much-wanted oxygen torn from it by the usual routes of solution and osmosis, from hemoglobin to body-cell through blood-liquid, capillary wall, lymph, and cell-wall.

Carbon dioxid is carried from the cells to the lungs by a converse series of carbon dioxid pressures. As in the case of the oxygen (but in converse directions, as regards the lungs and tissues) solution and osmosis will provide for entry to and exit from the blood stream, but is inadequate to provide transportation in the blood stream. Therefore, again, as in the case of oxygen, the transportation needs are met chiefly by the combination of carbon dioxid with the hemoglobin, but, unlike the case of oxygen, this combination is with the protein portion, not the iron portion, of the hemoglobin molecule.

The automatic mechanism for ensuring that respiratory

movements will continue, and that they will continually vary in due correlation with the needs of the body, rests upon the response of the governing nerve center in the lower brain to variations in the amounts of carbon dioxid reaching that center in the blood vessels supplying the brain with the brains's own food and oxygen, and engaged in removing its own wastes. This center judges of the general metabolic needs of the body from the sample thus submitted to it, basing its decision chiefly on the percentage of carbon dioxid, and little on the amount of oxygen. Alarmed by too great an increase in carbon dioxid, it hurries the respiratory movements to secure more rapid elimination; but reassured by a fall below the usual amount of carbon dioxid (such as may occur through self-forced breathing) the center may not call for respiratory movements at all, even though there be a real need for oxygen, until the carbon dioxid percentage has reached the accustomed figure.

Will-forced respiration, by introducing oxygen and eliminating carbon dioxid in proportions quite different from and greatly in excess of the metabolic needs of the body, constitutes a notable instance of incoördination introduced by the higher brain. The holding of the breath in swimming under water is a similar but converse incoordination. In each instance, as soon as the self-forced incoördination ceases, the body attempts to correct the conditions resulting from the incoördination by a converse procedure, reducing or stopping the respiratory movements if they have been excessive, increasing them if they have been stopped.

CHAPTER IX

HISTORY OF HEAT IN THE BODY

Heat is our sensation of internal molecular motion, as sound is our sensation of certain outer forms of the motion of much larger particles on a far larger but much less intense scale. Any substance which has an intense molecular motion tends to part with some of it to anything with which it is in contact if that thing has a less intense molecular motion. In everyday language, anything hot tends to warm up anything else it can reach, thereby cooling itself in strictly equal proportion.

The heat stored in potential form by plants and introduced to the animal body in the various forms of foodstuffs is converted into actual heat by the combustion processes already outlined, and into energy, which is an equivalent of heat, or perhaps better, another form of heat. Heat as heat is measured by the calorie. The large calorie, used in dealing with body heat, is 1000 times as great as the small calorie, being the amount of heat that will raise the temperature of a liter of water one degree on the Centigrade scale or roughly will raise about one quart of water one and four-fifths degrees on the Fahrenheit scale. If converted wholly into energy this amount of heat would be capable of lifting a kilogram (which is the weight of a liter of water) about 426 meters, or roughly two pounds 1300 feet. The conversion of a given total of available heat entirely into energy is rarely accomplished, however.

Of the attempts of man to convert heat into energy through machinery the steam engine is an example. Coal

is combined with oxygen in the ordinary household heating furnace, evolves much heat, and the heat is distributed about the house as such; but in the furnace of a steam-boiler, which is intended to convert heat into energy, the heat is prevented as much as possible from general distribution, and is devoted as much as possible to heating a limited quantity of water. No useful conversion into energy occurs during the early process of "getting up steam," for the heat at this stage merely acts to raise the temperature of the water from whatever it may be to the boiling point. At this point water at 100 degrees Centigrade becomes converted into steam at the same temperature, the change requiring a considerable number of calories. In the form of steam, which is simply water in gaseous form, the laws of gases come into play, and continue in play so long as the temperature does not fall sufficiently to re-convert the steam into a liquid. Amongst other peculiarities of gases as distinguished from liquids is the tendency of the gas to expand. A toy balloon full of water will not appreciably diminish in size under the heaviest pressure, nor will it appreciably increase in size if all pressure is removed from it as by placing it in a vacuum. But treat a toy balloon full of gas in the same manner and it will contract under pressure to the size of an orange, while under a vacuum it will expand to any size which the size of the vacuum chamber will permit, or until the rubber bag bursts.

The tendency of the gas to expand is known as its pressure. It is obvious that the pressure of our toy balloon full of gas is greater when it is compressed into orange size than it is when of ordinary toy balloon size, since it requires a greater external force to reduce it to and keep it at this smaller size. The instant the restraining force is removed the gas expands until its pressure exactly balances whatever other restraining forces it may meet. In the case of the toy balloon filled with gas under

ordinary circumstances, this restraining force is in very small part the elastic contractility of the rubber; chiefly it is the general atmospheric pressure of about fifteen pounds to the square inch. As this varies, the rubber balloon will change its size slightly to correspond. This expansion of the gas is accomplished by conversion of its heat into the energy of its movement outward against the restraining forces which oppose its expansion. The hotter the gas (other things being equal) the more such energy it possesses and the greater the force of this push. Hence by heating a gas, *i.e.,* by supplying to it more energy in the form of the movements of expansion, we increase its pressure. So our toy balloon may be reduced to the size of an orange by cooling it sufficiently, although the external pressure upon it remain what it ordinarily is; or we may enlarge the balloon by warming it again to the point of bursting, the external pressure remaining unchanged. In ordinary life a toy balloon will be distinctly smaller at night or in winter than during the day or in summer, in the shade than in the sun, etc.

Steam is a gas, which when in the form of water, may be considered as existing in a most convenient very compressed form, in which it will remain pretty much, minus evaporation, without any effort on our part, until we are ready to let it expand and so, properly directed, do work for us. A pint of water, converted by heat into steam, will occupy 25 cubic feet under ordinary atmospheric pressure. By forcing this steam into a space much smaller than this we secure a much higher pressure. By so confining the space and designing its walls that we have what we call a piston-box, we can use this high expansive force to move the piston, and so we have converted our coal heat into energy available to us mechanically.

The heat which keeps the steam at a certain pressure

is converted into energy when the steam expands. Thus the steam which pushes out a piston loses just the heat which is the equivalent of the energy of that push. One can with a given quantity of coal warm a given building *or* drive a certain steam engine. But one cannot do both with the same amount of coal. So far as the heat derived from the coal is converted into energy, so far it is lost to the building as warmth. But the steam engine succeeds in converting into energy, at its highest point of efficiency, only about 10 per cent of the calorific value of the fuel. A great deal of the heat of an ordinary steam boiler is thrown out into the surrounding air and passes up the chimney. But even that amount which is employed as energy in tearing apart and keeping apart the particles of water in the form of steam is very readily converted back into heat and escapes through the boiler walls, leaving the steam just so much cooler, *i.e.,* just so much less powerful. It is possible to construct a steam-tight boiler, but very difficult, indeed, to construct a heat-tight boiler. In fact, most steam boilers operate at an efficiency considerably less than 10 per cent *i.e.,* more than 90 per cent of the calorific value of the fuel reappears as heat and not as energy.

The gasoline engine, in its most perfect form, has an efficiency of 20 per cent, the Diesel coal-oil engine of about 35 per cent. The maximum efficiency of the human appears to be about that of a very perfect gasoline engine, but the average efficiency is much below 20 per cent. To put it concretely, a man living on bread and water will evolve as heat at least all the fuel value of four out of every five loaves which he eats, and as energy at most only the fuel value of one. On a diet of 3200 calories (absorbed), it cannot be expected that more than 600 calories will be converted into external energy. Hence, whenever the energy output of the body is to be increased by a given amount, the heat equivalent sup-

plied in the form of additional fuel must be at least five times as great as the energy equivalent. Thus if a man is to undertake work calling for the expenditure in energy of the equivalent of 50 calories, over and above his present expenditure, he must have 250 calories more of fuel over and above his present income. Conversely, every additional output of energy, any form of exercise for instance, greatly increases the heat output of the body. Exercise and sweat are interchangeable terms in literature, since Genesis announced that man should earn his bread by the sweat of his brow.

Regulation of Heat Loss

When we reflect that the average body throws off every day heat sufficient to raise 150 pounds of water, about 44 degrees Centigrade, which is roughly equivalent to the amount of heat required to raise an average adult's body from the freezing point to a rather high fever point, it becomes very evident that the ridding of the body of this surplus heat is a most important item in the body operation. The retention in the body of five per cent of this amount means a serious state of fever, and the retention of ten per cent means ordinarily that death will swiftly follow. Although the danger of chilling the body is ever present in the minds of most persons, the fact is that we can stand a depression of surrounding temperatures to far below zero and, with heavy clothing, meet it with confidence, for by thus conserving the output of our own heat, self-generated, we can preserve the internal temperatures required for existence. But on the other hand, our surroundings cannot go much above body heat without grave dangers to the body, more particularly if the rise of temperature is combined with the presence in the atmosphere of high humidity.

How such raising of the body heat injures the body

we have not yet found out. Of course we know that sufficiently high temperatures will coagulate the protein substances of the body, but the body will have died, as the temperature increases, long before coagulating temperatures are reached. We are at liberty to suppose that many of the various very delicate chemical reactions, which occur every instant in the living body, amongst the doubtless tens of thousands of different individual chemical substances which there exist, and which in a state of delicate physico-chemical equilibrium compose the body, occur in proper sequence and balance only or chiefly at or very close to the temperature of 37 degrees centigrade (98.6 degrees Fahrenheit). This temperature we therefore call the normal for the human body. We know definitely that the ferments of the body, when removed from it, will exercise their functions best at about this same point. However this may be, we know that in health the body operates at a temperature range which is about two per cent only of its daily heat output, *i.e.*, that a failure to rid itself of its daily output of heat to the extent of retaining only two per cent of the total would send the body temperature up above its normal; and that every instant four-fifths of its total heat production at that instant must be eliminated from the body or serious results will follow. This means that on the average, about two large calories, or enough heat to raise a liter of water two degrees centigrade, must somehow be passed out of the body every minute.

How is this heat elimination achieved? Believing as we have every reason to do that the heat is generated initially in the cells of the actively metabolizing tissues all over the body, it is necessary to trace it from these internal furnaces to the surface of the body.

Heat after all is our sensation of intense internal molecular motion, as described at the beginning of this chapter. This molecular motion we call heat even when

we ourselves have no sensation from it, although strictly speaking it is only hot when there is some living thing to be affected by it with this particular sensation. So also there is no sound, in that sense, if there be no ear to hear it although exactly the same vibrations, etc., go in the "sounding" substance. The transfer of heat from the source of it to anything else goes on in two main ways. One is by conduction, *i.e.,* a transfer of the molecular vibrations directly from particle to particle in close contact with each other, as when one places a flatiron on the stove. The heat of the stove-lid travels then with no intermediary into the flatiron, the flatiron growing warmer and the stove-lid correspondingly cooler. If the fire were not continually renewing the heat of the stove-lid, both flatiron and stove-lid would simply divide the stove-lid's heat between them and in time both would be at the same temperature; that is, provided other neighboring things did not also proceed to adjust their temperatures also to the temperatures of the flatiron and the stove-lid.

But other things do just this, notably, of course, the air, which is in contact with both. This warming of the air in contact with the iron is an example of conduction. But such warm air expands (as do all things which are absorbing heat) and being free to move molecularly, it floats up through the cooler, *i.e.,* less expanded air about it, just as warm water rises to the surface of the cold in a kettle which is being heated at the bottom. Bulk for bulk, this warm expanded air is lighter than the colder air, and rises in it for the same reason that wood floats in water—because bulk for bulk it is lighter than water. Not only does the hot air pass upward from the hot iron, but it carries with it the heat, *i.e.,* the increased internal molecular vibration which has been set up in it. As it rises it parts with this heat to its cooler neighbors, cooling itself in exact proportion as it warms them. As more and more of the air particles become warm and ascend,

they warm more and more of the cold air to their own temperature and it becomes increasingly difficult for the following particles of warm air to find air particles cooler than themselves with which to divide their heat. Hence the ascending column of warm air rises further until it strikes the cold ceiling and at once is able to unload. This transfer of heat by carriage through traveling air particles, which is not unlike in principle the carriage of oxygen in the red cells of the blood, is known as convection. It is merely a form of conduction, however; in which the particle warned by ordinary conduction moves to a new point before warming another particle by further conduction.

The second great method of heat transfer is a most important one to us for it is the method by which the heat of the sun reaches the earth. Without it there would be nothing on this earth to study and no one to study it. It is also the method by which heat reaches across terrestrial spaces, as from an open fire to the surroundings not in contact with it and not in such positions as to be reached by convection. The walls of a room and the floor are thus heated, even though arrangements be made by which the warmed air all rises and passes out of the room; and they would be so heated even though the room were a vacuum, and had no air in it to act as a carrier of the heat. This method is known as radiation, and to explain it we have offered to us the hypothesis that, after all, what we call space, what we call a vacuum, has in it a substance, unfortunately called by the same name as a well-known anesthetic, ether. This substance, which is supposed for convenience to permeate not only all space but all matter as well, is warmed by the sun at the sun's surface and passes the warmth on with immense rapidity to all the universe, including our little speck of solid matter, the earth. Thus radiation itself, if this ether hypothesis be true, is a matter of conduction also,

but occurs by means of the ether rather than of any solid substance which we can see or feel or weigh. If ether permeates all matter, it follows that heat is radiated from the stove-lid of our illustration to the flatiron through the ether which permeates both and lies between both, as well as by direct conduction from particle of iron to particle of iron. Indeed, we may question if the ether be not essential to the conduction from particle of iron to particle of iron, since no two particles of the stove-lid are in true contact with each other, much less in contact with any particle of the flatiron. However, the terms conduction, convection, and radiation do indicate certain differences in the relations of heat-sources to heat recipients, which are conveniently thus distinguished.

To return to the transfer of heat from the cell to the outside of the body, it must be obvious that this can occur *by conduction* only if the successive particles in line from cell to surface are successively cooler from within outward, paralleling our case of the stove-lid losing heat to the cooler flatiron. This would permit the cell heat to pass in direct lines by the shortest path to the outside. But it may occur also by the cell unloading its heat to a moving medium (the blood), which passes on, taking the heat away with it, as convected air does, and ultimately transferring the cell-heat to the air in the lungs, and to the air in contact with the skin or, finally, by radiation, through the ether from the body outward to all surrounding bodies.

It is improbable that the first of these methods, ordinary conduction, can occur from the depths of the living body, although it does after death, for every one of the tiny blood-cells must be practically as hot as its neighbors, and therefore no one cell can relieve its neighbor of heat since all are already in an equal state of heat-equilibrium with relation to the other. Conduction, may, however, come into play in the thickness of the skin, conducting heat

to the surface. The second method does occur, however, and the amount of heat lost by each path to lungs and to skin has been determined, about ten per cent of the heat of the body being lost by the lungs, about ninety per cent by the skin. The third method, radiation from the depths to the skin can hardly occur in the living body and for similar reasons.

In the lungs the heat of the alveolar moisture is divided by conduction with that of the incoming air, which as a rule will be at least slightly cooler than the temperature of the body. Under those circumstances where it is not cooler than the alveolar moisture, no such transfer can occur. (Another method may then function, evaporation—to be discussed later.) The cooling of the alveolar moisture permits it to take over heat from the lymph, which in turn may then take over heat from the capillary wall which then cools the blood. Thus a continuous flow of heat occurs from blood to alveolus. A quite similar flow of heat by similar stages of conduction occurs from the blood in the skin capillaries to the surface of the skin, its last stage on the outward path being by conduction through the outer layers of the flattened corneous cells.

The driving force behind the elimination of heat from the body-cell to the skin is therefore analogous to that which carries the carbon dioxid and other wastes out from the body cell to the skin. Both carbon dioxid and heat diffuse from the point where they are in relatively high concentration to points where they are relatively low in concentration, the former by solution and diffusion through intervening liquids and membranes, the latter by conduction through the particles of the same liquids and membranes. Neither could escape directly to the surface of the body by direct lines drawn through the tissues to the points of lesser concentration, because this intervening area is already full of carbon dioxid and of

heat and would accept no more of either. Through this intervening neutral territory both are transported *in status quo* by the blood stream to the points where the lower concentrations of each permit their escape. The diffusion of a gas like carbon dioxid in a liquid or through a membrane is analogous also to the conduction of heat through a substance or from one substance to another in that the movements at all times are in reality in both directions, from and towards the point of greater concentration, but in much greater proportion in one direction than in the other, until a balance is reached; this balance being not a state of quiescence in the flow, but a state of exactly equal flow in each direction. Thus the tendency to reach an equilibrium of opposing forces is the fundamental tendency which is at the bottom of the most important functions in the body. On a grand scale also the same laws hold true. The sun radiates heat to the earth and the earth to the sun. The earth is warmed, not by all the heat it receives from the sun, but by the difference between what it receives and what it radiates. If there were another sun in our universe, identical with the one we have, both would radiate heat to the other, but neither would be warmed by the other, *i.e.,* neither would gain in heat from the other since what one gained from the one would be just balanced by what it gives to the other. In the absence of either, the remaining sun would lose by radiation to space the heat which, in the presence of its companion would be returned in kind to it. These suns would "keep each other warm," not by adding to the heat of either but by conserving the loss of both. It is in just this way that a mother keeps her baby warm by holding it close to her in her arms. Both mother and babe in health have the same body temperature, and radiate heat at the same degree. But at the points where their bodies are in contact, each radiates back or passes by conduction to the other the heat that otherwise they

would lose to the air about them and to their other surroundings. To this extent their radiation and conduction losses are minimized. In proportion to their respective radiation and conduction losses when they are apart, the baby's saving is much greater than the mother's, but she in no sense warms the baby by adding heat to its own, as she would if she were actually hotter than the baby.

Loss of Heat from the Body Surface

The contact of the alveolar air with the alveolar moisture, which is always present on the interior of the wall of the alveolus, the contact of the atmospheric air with the outer epithelial layer of the skin under all ordinary circumstances, provide the former a slightly cooler, the latter a definitely cooler substance to which the alveolar moisture in the lung, the outer epithelial layer of the skin, may part with the heat brought to them by the mechanically operated "convection" journey of the blood stream, and the short terminal conduction trip from the capillaries of the lung and skin respectively to the respective surfaces. Under the rarer circumstances, when the atmospheric air itself or any other substance that is in contact with the body is as warm as the body, this outward flow of heat must necessarily cease, so far as conduction is concerned; while if the air or other substance in contact with the body be warmer than the body, the flow reverses, and the body is definitely warmed. The same situations arise in relation with substances not in actual contact with the body, but having radiation exchanges with it.

In any of these circumstances, heat retention in the body must ensue, unless (a) the heat production of the body can be correspondingly reduced, or (b) the heat elimination can be provided for in some other way than by conduction, radiation, or that form of conduction to the air combined with movements of the air

known as convection. This alternative method in the case of the living body is automatically provided by the evaporation of the sweat.

Without this alternative cooling process the body would be wholly at the mercy of the temperature of its surroundings for its heat elimination; so long as its surroundings were cooler than the body, heat elimination would be possible; but elimination would cease, with death as a quickly following consequence, at any time that the surrounding temperatures rose above, to, or even almost to the temperature of the body. It would then be no longer possible to survive a summer's day, if the temperature rose to 105 degrees Fahrenheit, to 98.6 degrees, or probably only to 95 degrees.

This alternative cooling effect is attained by utilizing the fact that conversion of liquid water into gaseous water, or steam, may occur at the temperature of the body, and requires for its occurrence that a large amount of heat be converted into the energy necessary to achieve this disruption.

As has already been indicated, a (large) calorie of heat is required to raise one liter of water one degree centigrade. It will raise one liter of water one degree centigrade, regardless of the initial temperature of the water to which it is added, between zero and 100 degrees centigrade. Thus one calorie will raise one liter of water at zero to one degree, at seven degrees to eight degrees, at 54 degrees to 55 degrees, at 98 degrees to 99 degrees, at 99 degrees to 100 degrees. But one calorie added to water at 100 degrees will not raise it to 101 degrees. However much heat is added to water at 100 degrees, the temperature of the *water* (under ordinary atmospheric pressure) will not be raised further. Instead, this added heat devotes itself to *disrupting* the physical structure of water, tearing its particles apart into steam. To achieve the disruption to steam of a liter of water will require

under ordinary pressure, *i.e.*, when water is boiling freely in the open atmosphere, about 500 calories.

In order that evaporation or conversion of water into water vapor shall occur, it is not necessary that these 500 or so calories shall be added to water already at the boiling point. Water will evaporate, although slowly, as everyone knows, at room temperature, or at lower points. Ice itself evaporates, readily in summer, but also even in winter. The number of calories required to evaporate a liter of water at temperatures below one hundred degrees is somewhat greater than at one hundred, because the cohesion of the particles to be overcome is greater at the lower temperatures.

If then the sweat poured out on the surface of the body from the innumerable sweat glands of the skin can be evaporated, its evaporation will use up that heat which the skin must part with to avoid heat retention in the body. An average of about two pints per day of sweat is provided by these sweat glands, which are so numerous that if those from an ordinary adult were set end to end they would make a slender tube nine miles long. The evaporation of this two pints or so may therefore be counted on to take up about 500 large calories of heat per day, or about one-fourth to one-sixth of the total output of the body.

It is not sufficient, however, that this sweat be produced on the surface of the body as water. No cooling effect from sweating can be obtained unless the sweat be evaporated. One must carefully distinguish between what is usually called "sweating freely," *i.e.*, the condition when sweat is being poured out in quantities evident to the naked eye as water, often streaming down the face and body in little rivulets, and the condition in which the sweat, although perhaps passing to the skin surface in equal or greater quantities, is evaporated as fast as it reaches the skin, and so does not appear to the eye at all.

In the former case (sensible perspiration) the escape of the water is obvious, but the very fact that it is in the form of water indicates that its cooling effect is *nil,* to the extent that it remains as water. In the latter case (insensible perspiration) when no sweat is to be seen, the maximum effect of cooling is being produced by whatever sweat is escaping. One may distinguish this insensible perspiration from a condition where no secretion of sweat is going on, by putting on a loose rubber glove. This prevents evaporation of the sweat of the hand on which the glove is placed, and if any sweating is going on the interior of the glove will soon become moist and slippery.

What factors decide that sweat if freely provided at the skin surface shall or shall not be evaporated,—shall or shall not absorb as energy, the heat of the body? Or very concretely, why during active exercise does the sweat show at times, at other times not? The answer to this involves a minute understanding of the physics of evaporation which is thoroughly well worth understanding, since some of the most real aids which hygiene can give to bodily operation depend on it.

Briefly, the evaporation or non-evaporation of the sweat produced depends on the relative amount of moisture already in the atmosphere. If the atmospheric humidity is high, evaporation is retarded; if low, it is encouraged. To correlate this with what we already know of the ways of water-vapor, let us imagine a liter of water at 99 degrees centigrade being brought to a boil in an open vessel, freely exposed to a good current of air, which carries off the vapor as it is formed. We know that under these circumstances, the first (large) calorie of heat which we add to the water at 99 degrees will raise it to 100 degrees. Thereafter all the heat we add will be converted into transforming the water into steam, *i.e.,* will be converted into energy, and will not further raise the temperature

at all. It will take about 500 calories to completely evaporate the water, about five times the number required to bring it from the freezing point to the boiling point. But for the diversion of this heat to energy in the bringing of the water to steam, the water would have reached the temperature of six hundred degrees centigrade by the time that this amount of heat were added to it. To achieve this, it is essential that the heat shall not be diverted to energy. If we imagine the water confined instead of exposed in the open, in such a manner that there is no free space above it at all, as by filling a container absolutely full and plugging it absolutely tight, we can then heat the container and the contained water far above the boiling point, without producing any boiling, *i.e.,* without the formation of any steam. Needless to say the container will have to be of the strongest construction to withstand the tendency of the heat to convert the water to steam. If the plug be removed when the temperature reaches approximately 600 degrees centigrade, the whole of the water would be converted into steam instantly, this steam having a temperature of 100 degrees centigrade; the other 500 degrees would be taken up in the conversion. In ordinary life, however, neither of these extreme conditions are found, *i.e.,* the steam production is never wholly prevented nor wholly freely developed. In a laboratory autoclave or the similar steam-under-pressure devices used in the surgical sterilizing room of a modern hospital, the boiling begins with a free space above the water, with at first a small open outlet. The steam first formed fills this space, driving out the air. So long as the steam escapes freely, the boiling of the water which supplies the steam proceeds at 100 degrees; but if the steam does not escape freely, either because the outlet is too small, or because it is purposely closed, the steam accumulates. At a certain point, the pressure of the steam above the water will balance the energy being exerted at

that temperature so that no more steam is formed, or rather the conversion into steam of the water is just balanced by the conversion of the water into steam. It is possible to so adjust the amount of heat supplied that this balance is maintained indefinitely, neither water nor steam either losing or gaining in bulk, and neither gaining in temperature, the heat supplied being used to make up the heat loss from the autoclave to its surroundings. The autoclave is continually losing heat by conduction, convection and radiation. It is therefore continually tending to become cooler. In order that the steam and water shall be kept hot, we must supply this heat thus lost. If now we add more heat than is thus lost, the additional heat devotes itself to breaking up more water into steam. This, because the outlet is closed, means more molecules of steam per cubic inch of space in the autoclave, *i.e.,* a higher pressure. We shall find that the water no longer becomes converted into steam when it is at 100 degrees. It must now reach a temperature of 103 or 105 or some other such temperature, in strict proportion to the steam pressure. We may adjust the heat supply again at this higher level, so that the heat losses to the surroundings are just balanced by the heat added, and then there will again be no increase or diminution in either steam or water. But there will be less water and more steam than at the lower temperature and both will be no longer at 100 degrees, but at 105 or whatever the particular balance between the steam pressure and the effort of the heat to form more steam requires. The point of interest is that we can at will increase the amount of molecules of steam, in our autoclave, at the expense of diminishing the amount of the molecules of water, by raising the temperature; or diminish the number of molecules of steam, increasing those of the water in like proportion, by lowering the temperature. Increasing the temperature, because it converts the relatively small bulk of a few drops of water into the

relatively large bulk of steam, will increase the pressure, and conversely, allowing the temperature to fall, by converting a relatively large bulk of steam into the relatively small bulk of a few drops of water, will reduce the pressure. At all times, however, under the conditions described, we would have had in the autoclave all the steam that it was possible to have at the temperatures reached. This condition of the space above the water in the autoclave is known as saturation; the space is said to be saturated with water vapor: *i.e.*, it can hold no more. If now, while our autoclave is in balance at, let us say, a temperature of 105 and of course at a steam pressure corresponding thereto, we open the outlet, two things will happen, correlatives of each other. The steam escapes because the atmospheric pressure is lower than that of the steam, or in other words the steam expands, filling, if we measure it, a much greater space than before. If we let it out into a temperature of 100 degrees, it will remain steam. If we let it out into a temperature, as we usually do, of the general atmosphere of the room in which we are working, most of the steam will promptly condense back into water, because it promptly is cooled far below 100 degrees. The point is that the steam as it expands, from its pressure at 105 degrees to its pressure at 100 degrees, cools. The heat which was distributed over so many cubic inches of steam in the confines of the autoclave is now distributed over a great many more cubic inches of the expanded steam. If we could compress this steam back into its former compass we would find that it had also its former temperature, always provided that we were able to prevent loss of any of the heat by radiation, etc., or to supply enough more to make up for any loss that did occur in the interim. Thus the steam, released from pressure, both expands and also cools. What happens to the water in the autoclave? It also cools promptly on the release of the steam pressure, passing downwards from its pre-

vious 105 degrees to 100 degrees, boiling fiercely the while because during this period it is under a comparatively low pressure (atmospheric pressure) for its temperature. When it reaches 100 degrees, which is the temperature corresponding with atmospheric pressure, it will continue to boil until it is all evaporated, so long as that temperature is maintained and the pressure is not altered.

We see now that the amount of steam which a given space is capable of holding as steam depends upon the temperature maintained in that space. The pressure depends upon the amount of steam in the space, and therefore also is directly proportional to the temperature. If we wish to get more steam *into a given space* we must force it in under a greater pressure which means a higher temperature. If we lower either the temperature (which results in condensation of some of the steam to water) or the pressure (as by allowing some of the steam to escape) we shall have less *steam in the same space.*

So much for the steam situation when the space containing it has all that it can contain at the given temperature and pressure. But suppose we begin our autoclave experiment all over again, with so little water in it that all is evaporated before the steam formed has driven out the air. If now as soon as the water is all converted into steam we close the outlet, the temperature up to that time being necessarily 100 degrees, we shall find that if we continue to add heat, the *temperature mounts very rapidly,* more so than under the conditions of the first experiment at a similar stage. This is because the heat we are now adding is not, as in the first experiment, being converted into energy and used to disrupt the water into steam, but is being added directly to the steam (and air) as heat. Now note that at these higher temperatures the space in the autoclave, now at a temperature of say 105 degrees, contains far less steam than that space is capable of contain-

ing at that temperature. It contains only this small amount, not because it is saturated by that amount, but merely because there is no more to be had. If we feed into the autoclave a small amount of additional water, it will instantly be converted into steam and join the steam already present. This addition of steam may be continued in this way until the space is saturated, *i.e.,* will contain no more steam at the temperature existing.

Suppose now, when the autoclave space is just saturated, at say 105 degrees, by the evaporation of all the water we have added, we raise the temperature again, say to 110 degrees. The space at this temperature could contain much more steam than is present and is therefore again below its saturation point for this temperature. Again by adding more water, which again will be at once converted into steam, we may again reach saturation point for this new temperature. But we can reach *saturation point* without adding water, in the last instance, by merely cooling the autoclave back to 105 degrees, since at this lower temperature the space we are using can hold only the amount of steam which is actually present and no more. If now we continue to lower the temperature, the steam will be condensed into water.

Short of the saturation point, the amount of steam actually present as steam is dependent on the amount of water available for conversion into steam, and the temperature. The additional presence of air does not enter into the problem, for the steam acts as any other gas would under the law of partial pressure; *i.e.,* it evaporates and condenses, etc., irrespective of other gases present.

Exactly the same conditions govern the evaporation of water from the body at the temperatures of the body, or the evaporation of water from the surface of lakes, seas, rivers, marshes, or wet soil, at any of the various temperatures these may have. The controlling factors are the amount of water available and the temperature. In still

air, whatever its temperature, a large body of water, a lake, a marsh, a well-saturated soil, will evaporate its water until the atmosphere above it is saturated. It is true that the atmosphere above it is not heat tight nor like the autoclave, steam tight. But the loss of heat from a great body of atmosphere such as that overlying a large lake, in still weather, goes on very slowly. The loss of vapor by diffusion through the atmospheric layers is also slow. In still air, therefore, the rate of evaporation from the water may easily be so much more rapid than the loss of vapor by diffusion that the local atmosphere becomes nearly or quite saturated. After the saturation point is reached for the temperature existing, no more water will be evaporated, until the temperature rises still further; while if the temperature should fall, the capacity of the atmosphere for water vapor is reduced, and the surplus vapor is condensed, forming dew, mist, rain, etc., according to circumstances but in each instance reverting to water.

If, before saturation has been reached at a given temperature, the temperature fall, the capacity of the atmosphere for water vapor is reduced, and the water vapor already present may be enough to saturate it at the new temperature, or be too much, so that some of it reverts to water. Even though the temperature does not fall all the way to the point where the water vapor already present is sufficient to saturate it, it is evident that the partial fall has reduced the amount of water vapor which need be added to secure saturation, as compared with the amount which was needed before the fall of temperature.

Thus for each temperature, under ordinary atmospheric pressures, the atmosphere can maintain as water vapor a fixed quantity of water and when it does contain this amount of water vapor it is said to be saturated. But the atmosphere at any given temperature does not necessarily or usually contain all that it could contain at that temperature. Winds, ascending air currents, fluctuations in

temperature, lack of available moisture for conversion into water vapor, all have their part, in addition to diffusion, in disturbing the process of saturation. The amount of moisture which a given part of the atmosphere does actually contain at a given time is known as its absolute humidity, and is expressed as the weight of water present in a given space, so many grains per cubic foot, for instance, or so many grams per cubic meter. This absolute humidity may be sufficient to saturate the atmosphere at that temperature, thus constituting one hundred per cent of the amount which the atmosphere at that temperature can hold. It may, however, be much less than this, say half as much, or fifty per cent, of the amount necessary to saturate. Whatever fraction the absolute humidity may be of the *amount necessary to saturate,* this fraction is known as the relative humidity for that temperature. Suppose, for instance, that the temperature of the air is 25 degrees centigrade, and that its moisture *condenses* at 10 degrees (*i.e.,* the air is saturated); we know from experiment that at 10 degrees centigrade, saturated air contains 9.33 grams of moisture per cubic meter; but at 25 degrees centigrade it could contain 22.796 grams; *the relative humidity* of the air therefore, is 9.33 :22.796, or approximately 41 per cent.

The absolute humidity is the amount of water which the atmosphere does hold. The relative humidity is the fraction which this amount is of what the atmosphere can hold. There are two processes by which the relative humidity may be altered. One is obviously the addition or subtraction of water vapor, *the temperature remaining the same,* thus increasing or diminishing the absolute humidity, and therefore increasing or diminishing the proportion which it is of the maximum capacity of the atmosphere at that temperature. The other less obvious process is the raising or lowering of the temperature, *the amount of water vapor remaining the same.* If the temperature rises the absolute humidity remains unchanged, but the latter is now a

smaller fraction of the increased capacity for water vapor which the atmosphere now has at its higher temperature.

Conversely, if the temperature falls, the absolute humidity remaining unchanged, the latter is now a larger fraction of the diminished capacity for water vapor which the atmosphere now has at its lower temperature. If the temperature fall sufficiently, the unchanged absolute humidity may become one hundred per cent of the diminishing capacity of the atmosphere or even more, whereupon it will be precipitated out as water.

It is then this relative humidity which controls evaporation of sweat, *i.e.*, not the absolute humidity but *the absolute humidity in relation to the temperature of the atmosphere.* Plenty of moisture may be provided on the body surface, and plenty of heat may be supplied by the body to evaporate it, but if the atmosphere is already saturated, evaporation cannot take place. If the atmosphere is already near the saturation point, but little evaporation can take place before that evaporation itself (in still air) will have raised the total water vapor to the quantity sufficient to saturate the atmosphere and so stop further evaporation. In a current of air, this reaching of saturation will be prevented or slowed by the continuous removal of the air nearing saturation point as the result of the evaporation, and the continuous supply of new air not quite so near that point.

Thus we may look upon temperature as the fundamental factor in evaporation directly into the general atmosphere, with relative humidity as a correlative; and air currents as a mechanical auxiliary, transporting the vapor away bodily as heat is carried by convection, or oxygen and carbon dioxid are carried by the hemoglobin of the blood.

Heat Loss Under Various Circumstances

It has been shown in the previous chapter that heat is lost by the body (a) directly to surrounding objects, of

which the air is the most universally and intimately concerned, and (b) by evaporation of sweat. The former passes out the heat from the body as heat, the latter converts it into energy. About four-fifths of the body heat is parted with by the first method, about one-fifth by the second. The various combinations of heat, humidity, and circulation in the air about the body largely govern the exact proportions in which these two methods are employed. These may be classified roughly as hot air, moist and dry, still and moving; and cold air, moist and dry, still and moving. The ideal conditions for ordinary indoor life are held to be a temperature of approximately 60 degrees Fahrenheit, a relative humidity of about 50 to 60 per cent, and a barely perceptible movement of the air horizontally, which means a flow of air of about 2½ feet per second. The terms hot and dry, moist, still, moving, should be interpreted in relation to these approximate standards.

Hot Air, Moist and Dry

Hot air in itself fails the body as a cooling agent in proportion as its temperature rises to that of the body, and above that of the body its cooling effect is negative, *i.e.,* it yields heat to the body. When hot air is also dry, however, this failure to cool the body directly is made up for, even to too great an extent at times, by its ready absorption of water vapor from the body, with the consequent cooling effect on the lung and skin surfaces. Thus in winter, in the drier parts of North America, low atmospheric temperatures out of doors mean a low *absolute* humidity of the air, *i.e.,* a cubic foot of air contains but a comparatively small amount of water. This is true even though the amount of water present in this very cold outside air be all, or almost all, that the air can hold at that temperature, *i.e.,* even though the relative humidity be near or at the saturation point.

When this air is introduced into a house and warmed, it is raised 30, 60, perhaps 90 degrees, without, as a rule the introduction of any new supply of moisture. Hence its relative humidity is immensely reduced, *i.e.,* its capacity for containing water vapor is greatly increased.

The chief supplies of moisture which this water-hungry air has available to it continuously are too often the persons inhabiting the house; and their perspiration is evaporated as rapidly as it is formed. The temperature of 60 degrees above noted as ideal, if combined with a relative humidity of 50 to 60 per cent, results when combined with the much lower humidity thus offered, in a definite chilling of the body, especially when the body is at rest, or comparative rest, as in sitting, reading, sewing, etc. It is well known that a temperature of 68 or 72 degrees, or even higher is often demanded for comfort in such dry atmospheres.

The attempt is often made to raise the relative humidity indoors in winter by various devices for permitting the evaporation of water from pans, etc., set about the furnace or at various points about the house. But ordinarily the amounts thus evaporated are quite inadequate because it is forgotten that it is not sufficient to supply enough to raise the cubic contents of the house once only to the required humidity, or even once a day, but many times a day, depending upon the number of times a day the air of the house is renewed. Most methods of house warming, dependent as they are on bringing in fresh outside air through the heating chamber of a furnace, pour this air into the house at a rapid rate, more particularly when the outside temperatures are very low.

This air as it comes in is very low in both heat content and water content. The furnace increases the former immensely, but the latter not at all or very slightly. Hence the hot dry air seizes upon any moisture available in the house and then escapes very readily through the in-

evitable cracks about loose-fitting doors, windows, etc., and through the walls themselves, taking its heat and humidity with it. Thus the furnace and any humidifying device that may be used are called upon to warm and to humidify a regular river of air, flowing continuously through the building to the outside. When artificial ventilation systems, designed specifically to hasten this flow through especially designed channels are in operation, these demands for heat and for humidity are increased in proportion to their efficiency.

The dweller in this cold dry climate, on leaving the hot dry house passes to a temperature that is quite adequate to provide for his heat elimination needs by conduction, convection, and radiation, without invoking the aid of evaporation. The capacity of the dry cold air for moisture is comparatively slight at most, and the body, getting rid of its heat fast enough by the other methods, even too fast perhaps, restricts the production of sweat. The skin capillaries are usually held to be diminished in size when the skin is exposed to cold, and the blood is routed largely by vessels other than those that supply the skin. It is true that the face and hands exposed to the outer cold usually become red, implying a greater rather than a lessened circulation. This has been explained as the attempt of the body to warm those particular areas most exposed, to prevent freezing. However this may be, it is true that the relatively small evaporation from the skin which occurs in cold dry weather is probably the chief reason why quite extremely low temperatures can be borne with comparative comfort if the air be dry.

Moist Air, Hot and Cold

When *hot* air, itself so poor a cooling agent, is also *moist,* the cooling resources of the body through evaporation are greatly minimized. If the air is too saturated with heat to remove heat from the body directly, and the air is sat-

urated with moisture also, death from heat-stroke will quickly supervene, unless the conditions are promptly altered. The readiest resources for heat removal then lie in utilizing water derived from other sources than the body at low temperatures, or ice, if available, or other cool objects which may absorb the heat directly. In a confined space, the moisture may be absorbed by hygroscopic chemicals, as in diver's suits, but ordinarily a change of place will be necessary, usually to a higher altitude, or into the ground, into a cave, or cellar, for instance. If either the heat or the humidity are not so extreme as to prevent *all* heat loss, but only such as to prevent a *sufficiently rapid* loss, currents of air may be utilized to hasten the removal of the heat or of the air immediately surrounding and saturated by the body.

In cold moist air, one might at first imagine that the absence of evaporation due to the moisture, would, by reducing heat loss through sweating, conserve the heat of the body, which would then be removed only by conduction, convection, and radiation, through direct contact with the cold air itself. But it will be remembered that even in cold dry air, sweat evaporation does not greatly occur and therefore is not an important factor in cooling the body. The further restriction on sweat evaporation imposed by the atmospheric moisture will not, therefore, really greatly affect the situation. On the other hand, on account of the high specific heat or thermal capacity of water vapor, compared with air, cold water-vapor in contact with the skin will require about twice as many calories of heat to raise it to skin temperature as will cold air, other conditions being equal. It is evident that the body on this account will lose heat very much more rapidly to cold moist air at the same temperature than to cold dry air. It is the universal experience of every one that cold moist atmospheres are more chilling to the body than much colder, dry atmospheres.

Effect of Air Currents

In general the effect of air currents, hot or cold, moist or dry, is to cool the body, by a horizontal convection of the air which has already been in contact with the body, has become to some extent warmed by the body, and has to that extent lost its further cooling powers. So long as such air remains in contact with the body, warmed and humidified by the body, it forms a blanket about the body which, if wholly undisturbed, will stop all further cooling, either by direct transfer or by evaporation. It is true that heat may be lost by the outer surface, so to speak, of the air blanket by conduction, convection, and radiation, but especially in hot weather the difference between the temperature and humidity of the blanket and that of the external air may be slight, and these diffusions slow. In winter, the blanket of warm air about the body, warmed by the body itself, is a decided asset in keeping the body warm, and one of the chief functions of clothing is to retain this blanket. Hence the reason for loose clothing and for multiple layers of clothing, or other devices for trapping and holding as much air as possible. But in the winter, the difference between the temperature and humidity of the blanket and that of the outer air is much greater than in summer, so that the blanket is much less a conserver of heat in winter than in summer; hence the wearing of as few clothes as possible in hot weather and the use of air currents to drive away such remnants of the blanket as may remain.

A current of air that has the temperature of the body and is saturated with moisture can do no possible cooling of the body, but a much hotter current of air that is also dry may be of benefit by encouraging evaporation. Cold currents of air, moist or dry, strong enough to carry away the atmospheric blanket of the body are immensely powerful chilling-agents. Very low temperatures may be borne

with comfort in still air although death by freezing may follow if a very slight breeze should spring up.

Movements through the still air are equivalent in cooling effect to a current of air playing on a still object, but when the movements are self-developed, as when a man walks or runs, the increased heat production due to the increased metabolism of the muscles used may be sufficient to offset the cooling effect of the blanket dissipation secured. In fact, running to keep warm is an example of the exercise much more than offsetting the cooling effect of the air current.

Swimming, when the water is cooler than the body, tends in the same ways and for the same reasons to increase the cooling effect of the water, as compared with simple immersion in the same water, without motion, and in like manner may be offset by the increased metabolism of the swimming exercise itself. Immersion in water does not preclude sweating, but it does wholly preclude the evaporation of the sweat. Hence, prolonged immersion in water close to or at the temperature of the body means cutting down or cutting off the heat elimination of the body during the period of immersion, except so far as parts of the body, the head, etc., may be exposed. In the case of divers or firemen, suits have been devised which interpose a layer of air of a suitable temperature to cool the body sufficiently between the body and the outer wall of the suit. By constantly renewing this layer of air as it becomes too warm or too humid, the man in the suit may face very varied temperatures in his external surroundings with impunity. The analogy between this artificial air blanket and that described as existing in more or less complete form about all of us is obvious.

Relation of Skin Surface to Heat Loss

The larger an object is, the less surface will it have in proportion to its cubic contents. An inch cube has a

volume of one cubic inch and a surface area of six square inches,—ratio, 1 : 6; a two-inch cube has a volume of eight cubic inches and a surface area of twenty-four square inches; ratio, 1 : 3; a three-inch cube has a volume of twenty-seven cubic inches and a surface area of fifty-four square inches; ratio, 1 : 2—the ratio between volume and surface decreasing as the volume increases. The skin of an average adult which contains about sixteen square feet, or about one and a half square meters, is much smaller in proportion to the actual bulk of the body than is the skin of a child in proportion to the bulk of its body. Hence the heat-radiating surface of a man is much less than the heat-radiating surface of a child in proportion to the active, living, heat-producing substance for which it acts as radiator. One of two things must then be true. If the metabolism of the adult proceeds at the same rate per cubic inch of body as does that of the child, the adult must necessarily lose his heat much more rapidly per square inch of skin than does the child, and the skin of the adult must average a higher temperature than that of the child; or else the metabolism of the adult proceeds at a lower rate than that of the child does.

But the skin of the adult and the skin of the child under similar conditions have about the same average temperature, the child's perhaps being slightly higher. It must, therefore, be true that the metabolism of the adult proceeds at a lower rate than that of the child, cubic inch for cubic inch, or weight for weight. This might reasonably be inferred from the much greater proportionate activity of the child in growth, its greater proportionate intake of food and oxygen, and also, after infancy, its great display of external activities. As a matter of fact, the daily heat output of a young child is, pound for pound, rather more than double that of the adult (100 cals. per kilogram for the former, about 40 cals. per kilogram for the latter). This is compensated for by its greater area of cooling surface.

Effects of Heat Retention

The heat thrown off every day by the average body is sufficient to raise the temperature of 150 pounds of water 44 degrees centigrade, or to raise the ordinary temperature of the ordinary adult to the boiling point of water in about thirty-six hours. It is very evident that ridding the body of surplus heat is a most important item in body operation. The retention in the body of five per cent of this amount means a serious state of fever, and the retention of ten per cent means that death will speedily ensue. Although the danger of chilling the body is ever present to the minds of most people, the fact is that we can stand a depression of surrounding temperature to far below freezing point, and with heavy clothing, meet it confidently because our own body-generated heat preserves the internal temperature required for existence. But on the other hand, our bodies cannot without grave danger, endure an external temperature much above the normal temperature of the body, particularly in an atmosphere of high humidity.

The processes by which an increase of body heat injures the body have not been ascertained. Sufficiently high temperatures coagulate the proteins of the body, but death occurs long before these temperatures are reached. We are at liberty to suppose that many of the various delicate chemical reactions which take place every instant among the tens of thousands of chemical substances in delicate physico-chemical equilibrium in the living body, occur in proper sequence and balance only or chiefly at or very near to a temperature of 37 degrees centigrade (98.6 degrees Fahrenheit). We know definitely that the ferments of the body when removed from it, will exercise their functions best at about this point.

Whatever the explanation may be, the fact is that in health the body operates at a temperature range which is

about two per cent only of its daily output; in other words, a failure to rid itself of all but two per cent of its daily heat output would send the body temperature above the normal; and at every instant the body must eliminate four-fifths of its total heat production at that instant or serious results will follow.

In warm temperatures, the body eliminates heat more rapidly by dilating the peripheral capillaries, by sweat evaporation, by increasing the rapidity of respiration and circulation, but these activities mean increased metabolism in the muscles and glands involved and a corresponding increase in heat production. To offset this there is a general decrease of metabolism in the body. Hence the lassitude and drowsiness in hot and especially in hot humid weather. The "lazy feeling" is really the result of conservative measures on the part of the body in an effort to reduce metabolism. Dislike for solid food, the choice of light, cool foods and cool drinks, aversion to exercise or labor, tendency to discard clothing, are all effects of Nature's efforts to reduce metabolism and increase the elimination of heat.

When all such means fail of effect, there is a last desperate effort to get rid of heat by frequent elimination of the warm water of the bladder. Cessation of sweat and frequency of urination are cardinal signs that the danger zone has been entered. The temperature may reach 110 degrees Fahrenheit and respiration may fail. Relief measures are artificial respiration and oxygen inhalation if necessary, spraying the body with cool water or rubbing it with ice until the temperature is not more than one or two degrees above normal.

Summary

The heat of the sun, brought into the animal body in stored form by foodstuffs, is released in the body cells as

heat, and about one-fifth of this heat is converted into motion, which does the work of the body. The rest is eliminated to the surroundings of the body as heat. The maintenance of the body heat (in warm-blooded animals) at or about 100 degrees Fahrenheit (98.6 degrees Fahrenheit in the human) is essential to successful body operation, and therefore the heat continually set free in the body during life must be as continuously passed out from the body, to avoid an accumulation of heat in the body. This elimination must average about two large calories per minute at all times for the average active adult. A range of two per cent in approximating this heat loss is all that can be allowed for variations without either heat accumulation or heat loss. Heat loss in excess of the needs of the body must also be avoided. failure in either direction leads to ultimate damage.

This heat elimination is achieved chiefly by the mechanical transportation by the blood of the heat from the body cells to the surface of the lungs and skin; and then from the latter to the outside world by conduction, convection, and radiation, always provided the outside world available for the purpose is at a temperature sufficiently lower than that of the body to take over the amount of heat thus presented to it. When such outside temperatures are only slightly below that of the body, such heat transfer may not take place fast enough, and if the outside temperatures are equal to that of the body, heat transfer will not occur at all. If the outside temperatures are greater than that of the body, the flow of heat is reversed and the temperature of the body tends to be directly raised. Under all such circumstances, the heat of the body, otherwise inevitably retained to the detriment and even death of the body, may be disposed of by converting it into the energy required for the disruption of water into water vapor. Where sweating occurs, the body automatically provides this water at the temperature of the body, to the extent of about a liter a

day in the ordinary adult. Where for any reason sweating ceases, a thin layer of water supplied artificially from the outside may take its place. This water will in its evaporation convert about 500 to 600 calories per day into energy and so get rid of the heat.

It can do this only by evaporation, and evaporation can occur only when the atmosphere is not already saturated with moisture. The advantage to the body of evaporation is, that, provided the atmosphere is not saturated, cooling can be thus achieved at temperatures far above those which would prevent heat elimination from the body, if the elimination were limited to conduction, convection, and radiation.

At temperatures which do not permit heat elimination from the body except by evaporation, saturation of the atmosphere is fatal, because it cuts off this last resort also. Close approach to saturation is dangerous because the evaporation of the sweat itself may be sufficient to raise the humidity to saturation. A current of air, by mechanically removing the saturated or nearly saturated air, and bringing new air not quite so saturated to the place where evaporation is going on, may permit the successful cooling of the body, where the same conditions in still air would be disastrous.

The body automatisms thus provide for getting the air to the surface of the body and even the water to be evaporated. But thereafter the getting of the heat away from the body depends upon the temperature of the surroundings primarily, then upon the degree of saturation of the atmosphere, and under certain circumstances on the existence of air currents.

Modern ventilation concerns itself little, therefore, with the quality of the air from the standpoint of *breathing;* almost entirely with the quality of the air from the standpoint of *cooling* the body; the three main features to be considered being temperature, humidity and circulation.

PROJECTS FOR CHAPTERS VI TO IX

1. Explain under what circumstances one must perspire in order to be comfortable? Demonstrate by an experiment that water evaporated from a surface will cool it.
2. Outline a program for the care of the skin, explaining the use of all articles which you prescribe. Try out the program (if approved by the instructor) for a few weeks, then report on it. Discuss the value of a healthy skin from a business and from a social standpoint.
3. Outline the advice that an Industrial Nurse should give to persons working in "dusty trades" to prevent lung diseases and to keep the respiratory organs in good condition.
4. Prepare for use in the class room a diagram to show the transfer of air through the organs of respiration.
5. Enumerate and explain the adjustments made by the body in order to maintain the same body temperature in extremes of climate. Illustrate the principles by experiments.
6. Suggest "rules of health" that may be deduced from these chapters on Respiration.
7. Nurseries for premature infants sometimes need to be fitted out with a mechanism that regulates the humidity of the atmosphere in the room. How may this be accomplished?
8. Enumerate and explain the various ways by which the air in a home may be kept in desirable condition. Discuss the importance of desirable air conditions.
9. Devise a method by which the air in a patient's room may be made comfortable on a hot day.
10. Prepare a table comparing cotton, wool, and flannel, as material for under garments. Illustrate by experiments. What are your conclusions?
11. Make a study of the ventilating system in your school, and formulate recommendations that you think are necessary regarding it.
12. Prepare an explanation of the manner in which oxygen reaches the cells of the body and the manner in which carbon dioxide passes from the cells to the external air, basing your explanations on demonstrations of osmosis.
13. Demonstrate and explain the principles of conduction, radiation, and convection as applied to the maintenance of body temperature.
14. Make a collection of recent publications regarding carbon monoxid poisoning and prepare a report on the health

hazard from automobile exhaust gas in city streets, garages, and repair shops.

15. Give a detailed explanation of the factors that may cause a person working in a laundry to be overcome with heat. How could the condition be prevented? What would you consider a rational method of treatment?

16. Compare heat exhaustion and sun-stroke in respect to cause, body reaction, prevention, and treatment.

17. Read up the list of occupations in which dampness is a health hazard. Make a thorough study of one of these occupations and determine the health rules advisable to those who follow it.

CHAPTER X

PROTECTION

Protection is one of the three great characteristics which protoplasm shows when it is alive—the other two being Nutrition, already described, and Reproduction (more broadly, Race Maintenance).

Protection is a necessary correlative of nutrition, for *nutrition,* as has been shown, *includes all those activities, internal and external, of living protoplasm by which that living protoplasm secures to itself an income of food from its surroundings.* From the ultra-microscopic germ, through the ameba, the moss, the louse, the shrub, the wolf, the tiger, the deer, the elephant to the whale, and thus regardless of size, vegetable, or animal structure, or complexity, every living individual, including of course man, draws constantly upon its surroundings, animate or inanimate, for the energy it converts into its life processes, and for the materials which it converts into its own bulk. So far as the *animal* is concerned, in contrast with the plant, it draws very largely, all but exclusively, for its food, upon its animate surroundings, *i.e.,* upon other animals or plants or both, not upon its inanimate surroundings. Living animal protoplasm requires killed animal or plant protoplasm for its existence, and every living animal must keep a continuous flow of such killed protoplasm coming to itself or perish.

It is for this reason that protection is the necessary converse as well as the necessary correlative of nutrition. *Protection includes all those activities, internal or ex-*

ternal, of living proptoplasm by which that living protoplasm prevents its surroundings, particularly other living protoplasm, from securing an income of food, etc., from it. From the ultra-microscopic germ to the whale, every living individual, including man, is subject to be drawn on as food by other living individuals. It is true that not every species of plant or animal is thus subject to be drawn on by every species; but every species of plant or animal is thus subject to be drawn on by some one or more species. Thus the grass is subject to the sheep; the sheep to the wolf; the wolf to other wolves: the man and the germ being the most omnivorous of all, and eating each other freely as well. Doubtless the omnivorousness of man and of germ furnish an important factor in the survival, enormous numbers, and ubiquity of these two varieties of life.

But just as nutrition is not wholly concerned, even amongst animals, in securing other living things for food, so protection is not wholly concerned with preventing the attacks of other living things which are seeking food. Nutrition reaches out, even in the animal, not alone for living protoplasm but also for inanimate materials, water and salts particularly. Protection conversely provides against invasion not alone by other living protoplasm but also against invasion by inanimate things, against forces of all kinds, gravity, friction, etc., and against materials, air, water, and salts included; *i.e.*, against mechanical *and physical* injury, and against chemical poisoning. That the individual may survive it is not sufficient that he secure other living things for his own food, and escape forming food for other living things; he must also escape mechanical, physical, or chemical injury from those very surroundings which are necessary to him. He must secure air but escape damage from whirlwinds of the air; he must secure water but escape floods of the water; he needs salts but must provide against poisoning from salts; he needs

the soil but must guard against being crushed from the very earth and rocks which support his frame. The attacks of living things on each other have behind them the urge, the need for food, for survival. The reasons for their attacks on man are now clear; we call the attacks by different names, from "homicide" to "disease." The attacks of inanimate things on living things have no such urge, yield no advantage to the attacker, and we call them "accidents." But whether due to design or accident, such invasions of the individual must be prevented or the individual ceases to live. Protection includes all the measures designed to this end. Hence Nutrition on the one hand, Protection on the other, hold the balance between the invasive force of the individual directed against the rest of the world, and the invasive force of the rest of the world directed against the individual.

Thus each living thing seeks to continue to live by acquiring the assets of other things (Nutrition); and by preventing those others from acquiring its own (Protection). But Reproduction and its larger phase, Race Maintenance, in the higher forms of life, restricts the seeking of nutrition from others *of the same species,* and hence reduces the need for protection against others of *the same species.* In man, this restriction of the invasion of the individual by other members of his own species, and vice versa, has reached its greatest development. This is seen in its most elementary forms in anti-cannibalistic doctrines; in its highest forms in broad altruism and the doctrines of the brotherhood of man. Slowly, painfully, with immense incoördination and inconsistency, man has developed to a high point the art of living without physical invasion of his own species—but with the correlative and indeed unavoidable corresponding development of ruthlessly determined, systematic and insistent physical invasion of all other species. His food supplies are now no longer dependent on the haphazard struggles of one in-

dividual man with any haphazard individual animal who are brought together by accident; or even on the deliberate hunting of individual animals. Man now, instead of casually hunting, deliberately "raises" nations of other species, cattle, sheep, hogs, hens, etc., purely in order to eat them—and forests of grains, vegetables, fruits, nuts for the same purpose. Immense expenditures of labor and study have been devoted to the nutrition, protection and reproduction of those plant and animal species upon which man systematically preys, in order that he may bring them most successfully to the highest point of their own development, so that they may then most usefully serve his own needs. Without this vicarious sacrifice of the lower species, systematized, developed and carried on a high scale, man today (as seen in famine regions, even now) returns inevitably to physical attacks upon man. The foundation of a stable race of man lies, therefore, in his food requirement activities, *exercised on other species.* What we call "peace" is non-invasion of man by man, the correlative of intensified and systematized invasion of other species by man: and thus nutritional activities, the cause of warfare between unorganized individuals of the same species, becomes when thus systematized the strongest factor in the protection of the individual against his own species.

That which nutrition requires man shall do to others, protection requires he shall evade for himself. It includes two great subdivisions, protection against inanimate things and protection against animate things. In each of these great subdivisions the attacks on the individual may be made by mechanical, physical, or chemical methods; and the protective procedures are, therefore, necessarily of corresponding character. Mechanical, physical and chemical protection may be either of an active, aggressive, invasive form, or of a passive, resistant, inert form. Thus by swiftness the deer escapes the wolf, mechanically in-

creasing the space between himself and his attacker; the bird escapes the fox by moving above him into a tree; the fly escapes the swatter by dexterity. But the wasp, the lion, man himself, protects himself by counter attack, the best form of defence; while the lobster and the turtle oppose to invasion the passive protection of a relatively impenetrable armor. These illustrations, multipliable by the hundred thousand, apply to the mechanics and physics of protection; chemical protection is more intricate and is best illustrated in the development of what we call immunity to "disease." Mechanical and physical injuries have been understood for thousands of years as the cause, effects, cure, and prevention. But chemical injuries have but recently been understood at all and have been but slowly and painfully worked out, incompletely even today.

What then is "disease"? Disease in its broadest sense is merely a short-coming in nutrition, or in protection—a failure of protoplasm to function fully in these protoplasmic activities. To say the same thing in different words, it is a failure in adjustment of the protoplasm to its surroundings—a failure, therefore, in the most striking, most all inclusive and special characteristic of living protoplasm, *i.e.,* its ability to adjust itself minutely in detail and to its own advantage, to its surroundings and to changes in them. This failure may be in one or in several directions; it may be so slight and temporary as to be of little significance or so extreme and permanent as to result in death. Note here that every change in the surroundings requires some change in the protoplasmic adjustment thereto—and that those changes in the surroundings which occur abruptly in extreme form require equally abrupt or extreme adjustment, if life is to go on successfully—but that protoplasm *cannot* make abrupt or extreme changes without pain or damage. The very attempt to change adjustments to meet changes in the surroundings is, therefore, itself in the nature of disease. Successful change,

involving no evidences of pain and damage, do not call attention to themselves. But abrupt or extreme changes in adjustment are painful or damaging or both, even though ultimately successful; and disease is, therefore, the attempt at adjustment when it does not keep pace with the change or *rate* of change requiring the adjustment.

In those adjustments of living protoplasm to inanimate surroundings which are required, to heat and cold, to gravity, friction, etc., the same principles hold—that when these adjustments are made readily and easily, without calling attention to themselves, disease is not manifest; while if the adjustments called for are abrupt or extreme, pain or damage, or both accompany the adjustment; and this we recognize as disease. Thus the friction on a soft hand of a spade or paddle, if severe or prolonged, raises blisters; if gentle, slow and slight, hardens the hand until at length the severest use of spade or paddle produces no effect whatever. One may examine any instance of disease in the same way and detect the same principal running through it—disease is the very process of adjustment itself when so made as to be painful or damaging. But surely we do not call a blister on the hand a disease? Disease is something serious, severe, such as pneumonia, diphtheria, diabetes, is it not? True in ordinary language, disease means serious trouble; and the term disease grew up when it meant also those forms of serious trouble, *the causes of which were not clear.* From time immemorial man has fully understood mechanical and physical injuries, the invasion of the body by visible weapons, bows, arrows, clubs, stones, teeth, claws,—and such injuries were not a mystery to him. He inflicted them himself, on other men, animals, plants. When he inflicted them on other men he called the process *war;* on other animals, *hunting;* on plants, *reaping, threshing, grinding, cooking,* etc. But man has only recently seen that what he formerly considered a separate and distinct sort of invasion of the body—the

mysterious "attacks" of pneumonia, diphtheria, etc.,—and which he attributed to gods or devils because he could not see any mechanical, physical, or chemical cause, are after all just the same thing as war or hunting or reaping—attacks truly, but not of gods or devils—merely attacks of microscopic animals or plants, or of invisible but measurable physical, mechanical, or chemical forces—only mysterious while they are invisible, unmeasurable. Thus the application of the term "disease" today to certain forms only of pain and damage is merely a use surviving from the more ignorant past, when it was applied only to those conditions which our ancestors did not understand as contrasted with those that they did understand.

We see today that the "disease" of our ancestors is quite the same character as the war, hunting, accident, poisoning, which they did understand but due to more obscure, less readily appreciated attackers which, however, we now find were of precisely the same general character.

In fact, our microscopes and physiological researches have solved the age-long mystery of disease by showing that it is merely a continuation into the invisible world about us of the same struggles for existence we have long freely appreciated and taken active conscious part in, in the visible world.

In order to live, protoplasm must constantly adjust itself to its surroundings, at the penalty of pain, damage, death, according to its degree of failure to adjust. These adjustments necessary to life may be classed as first, activities directed to taking from its surroundings whatever the protoplasm needs to keep it going, or Nutrition; and second, activities directed to prevent its surroundings from taking from it those things its surroundings require, this constituting what we call Protection. These two, Nutrition and Protection, are the purely selfish, individualistic activities requisite to the successful survival of the individ-

ual. Without success for *some* individuals, thus surviving, *all* animal life would disappear. Reproduction or Race Maintenance constitutes similar activities, both in the direction of Nutrition and Protection, when exercised by the individual, not on behalf of itself, but on behalf primarily of its offspring; these altruistic activities broadening out into similar activities exercised on behalf of the community, the race, the species—and necessarily correlating with a corresponding intensification of warfare upon other species as warfare within the species diminishes.

We fundamentally distinguish *war*, *hunting* and *agriculture* by limiting the first term to the struggle within an animal species, the second to the struggle between animal species, the third to the struggle of the animal with the vegetable kingdom. The struggle with the inanimate things and forces of the universe has no specific name, but the broad term "trauma" or "injury" may be used to include the damage done by such things or forces when of a physical or mechanical character.

Protection Against Inanimates

Of the inanimate materials and forces of the world, the earth itself on which we are supported, the gravity which holds us to it, the air about us, and temperature, are examples of the great groups—matter, and force—with which we are continuously in contact, to which we must continuously adjust ourselves. Consideration of them will suffice to make the principles of protection clear. Proper adjustment to them are fundamental necessities for living protoplasm. Our adjustments to these particular things are made unconsciously and automatically to such an extreme that we are likely to be rather disturbed at first in considering them as things requiring of us any adjustment at all.

Gravity

Consider first gravity, which for our purposes is a constant drag or pull upon every particle of living protoplasm towards the center of the earth. This pull is opposed by matter interposed between us and the center of the earth—the substance of the globe itself. Between gravity, drawing us down, and the crust of the earth which stops our progress downwards, we are held at the surface of the earth more or less firmly. We move sidewise along this surface readily enough, *at right angles,* to the downward pull. We move *with it* only too readily, when nothing interferes, as in a fall down a well or staircase; we *rise against it* only with great expenditure of energy—our own, as in walking up a hill, or that of gasoline, as in ascending in an aeroplane.

We are so minutely adjusted to gravity, that our bodies may be put out of business altogether by merely inverting our ordinary erect position, death ensuing if one hangs by one's heels for any length of time. Bats, on the other hand, are adjusted to hanging head downward quite indefinitely and doubtless human bodies could adjust themselves in time to the same position, as certain Indian fakirs are said to have trained themselves to do. Indeed, we humans are only in part adjusted to the erect position and still require frequent returns to the prone positions for rest. The sick person almost automatically takes this position as the easiest, to meet the added strain of "disease," and in almost all treatment of the sick, rest in bed is the most fundamental and generally useful of all "first aid." In many "diseases" this is really not only the most effective aid, but really almost the only aid that can at present be given.

A further illustration of our minute adjustment to the pull of gravity is given in "sea-sickness"—a sickness by

no means confined to sickness on the sea, but in any swaying motion as on a swing or on a rough road.

From a study of our adjustments to gravity we may learn, as we may learn from the study of any other adjustment of the body, the fundamental lesson of hygiene—that any adjustment for which a potentiality exists at all may be developed by exposure to the condition calling for its exercise if that exposure be short at first, the demand be increased gradually, and if frequent intervals of rest be afforded during the development. Protoplasm requires frequent rest, even in those adjustments wherein it is perfect; but still more, when it is developing an adjustment which is as yet far from perfect. Fancy setting a young child just making its first steps to run a ten-mile hare and hounds chase! The principle involved in the child's development from those first staggering steps to a record marathon at the Olympic Games is just identically the same principle as that which governs all adjustments, even to immunity against smallpox or tuberculosis—possibly if we knew enough, to immunity against old age itself!

Mechanical Injury

It is an ancient adage that it is not falling that hurts, but stopping. Falling is but a particular motion in a particular direction—downwards. So that more broadly we may say that motion does not hurt us if it is not too abruptly ended. Again we have adjustment and its fundamentals coming into play—if we fall slowly, with gradual increase only and especially with intervals of rest, the falling itself is harmless. Contrast a man thrown naked from a balloon 1000 feet in air with that same man provided with a parachute, even if descending from a point 10,000 feet higher. Remember that we ourselves, the whole globe and all life on it, is moving about 30 miles a second through

space. To this motion we are fully adjusted. Yet imagine if we sprang suddenly from rest to this rate of motion—or from this rate of motion suddenly to rest! Either way the whole globe would dissolve in tenuous gas as the result of the abruptness of the change. We are adjusted to this rate of 30 miles a second in one direction. But spin around on your own feet a dozen times and you grow dizzy, perhaps vomit, perhaps faint—because you are not adjusted to such a sudden, even though relatively slight, change in motion. But the whirling dervishes of the Sahara have adjusted themselves to turning round and round like a top for long periods without any sign of damage to their bodies.

So strongly impressed on our every cell is the requirement for adjustment to gravity, to motion in general; so strong is the sense of the need for protection against the invasion with pain or damage of our bodies, by these forces, that even the apprehension of impending change will make many people dizzy or sick or faint—as when one, however firmly planted, looks over a precipice. A curious illustration of this same instinctive fear of failure of adjustment to gravity is seen in the fact that most of us would pace an ordinary three-foot sidewalk for miles and never dream of stepping over its edge by accident or falling on it. Yet set that same sidewalk fifty feet above the earth, without guard rails, and few persons would even attempt to walk it at all. There is absolutely no greater danger in the one case than in the other, yet imagination, the now instinctive recognition of the essential need for proper adjustment to gravity, the picturing in the mind of the results of the improbable and all but impossible failure to adjust is such that the adjustment is not even attempted.

Here also we have an explanation of the failure of some persons to recover from "disease," while others manfully survive "by will-power." It is merely that the latter at-

tempt the adjustments required, while the former over-imaginative, give up without attempting them at all.

How do we meet the force of gravity? By developing within ourselves adjustments to it. How do we develop those adjustments? By slow and gradual exposure to gravity with intervals of rest. How can we achieve slow and gradual exposures with intervals of rest, to gravity, an ever-acting, constant force? As for slow and gradual, is not that the very history of the growth of all new individuals, from the microscopic egg to adult life? Imagine a new-born infant required to support at once upon his little legs his adult weight. Intervals of rest? Yes; we cannot interdict the operation of gravitation, nor the direction of its downward pull. But we can and do continuously change the direction of the pull *in relation to our own bodies,* by changing the position of our bodies. Hold the hand low for a minute, fingers down; then hold it high, fingers up. Gravity, which pulled every cell in the direction of the finger-tips in the first position, now pulls every cell away from the finger-tips; and the effect can easily be noted by watching the veins upon the back of the hand—full with the blood drawn to the fingers in the first position; relatively empty of blood, now drawn to the arm, in the second.

Exercise

Exercise is largely a juggling with gravitation—an "exposure" of the body to gravity and the correlated effects that flow from it, friction, the opposition of the air, etc. When we appreciate this, we are the more likely to appreciate also that fundamental fact about exercise, namely, that it by no means merely indicates development of certain muscles; rather that it includes all sorts of adjustments of the body, nutritional (and therefore excretional) respiratory, circulatory, nervous and mental.

Whether any particular exercise taken be movements made merely for their own sake, or in the accomplishment of some end to which the putting forth of bodily effort is necessary—whether it be mere rising on the tiptoes or the digging up of a concrete sidewalk—exercise is an act which brings into play more or less a great number of adjustments; the exact extent of each depending on the form and continuity of the exercise. In fact, without accomplishing external work at all, the body works continuously against gravity, works continuously to maintain its own adjustments as living matter, puts forth generally even in sleep two-thirds as much energy as the same person uses in waking employments; for 1800 calories indicate the heat and energy of the body at rest, 2700 at moderate exercise. True the active soldier on a hard campaign may, in his daylight activities, push his total output up to 5400 calories or for short periods, push it still higher, up to 7000, a total output of about four times his basal figure. Such a man is performing external work to the extent of 7000 — 1800 calories or 5400 against 2700 — 1800 or 900 calories devoted by most of us to exercise. Such increases in the demands of gravity upon us are not to be lightly permitted without first being sure that all the adjustments called for, respiratory, circulatory, nervous and mental will meet the strain thus put upon them, not merely that our muscles will meet them. One most important field in which the development of the body to meet gravitational adjustments called for in exercise is that which deals not alone with strenuous exercise in what we call "work"—but also with strenuous exercise in what we call play. It is often pointed out that our industrial population "wears out," largely through overstrain, at an average age of 38. It is not always so well appreciated that our sports tend to wear out our devotees of athletics at much earlier ages. Spectacular sports, especially, call forth, supply, the "urge" necessary to immense exertion, and too often, in our

schools, to immense exertion by those not properly adjusted to it; constituting thus a more unhygienic lack of correlation between the mental and nervous adjustments with the respiratory, circulatory and muscular. Too often the ruthless urging of playmates, the pressure from over-eager trainers, has resulted in High School boys wrecking for life certain of their adjusting abilities, especially those involving the heart and blood-vessels, in the attempt to win a prize or make a record.

Sleep

While we may frankly admit that we do not know much about sleep, we do know that a valuable part of sleep consists merely in rest—for sufferers from insomnia do not necessarily suffer much bodily harm, provided they rest their bodies as sleepers do, notwithstanding that their minds are conscious, or even active, throughout.

Accidents

Physical and mechanical injuries, occurring from the sudden application of external forces for which the body is not at the moment properly adjusted, are called accidents as a rule, unless deliberately planned by enemies beforehand. From the standpoint of the body, however, the sudden application of an external force, when the body is unprepared for it, constitutes an accident whether the situation was unexpected or planned. If a tree fall on a man's leg, it matters little to the broken leg whether the tree fell by the planning of an enemy or not. If measles germs gain access to the body, it matters not that they came unplanned and unannounced, or by deliberate intention.

An interesting and common type of accident is that which comes from lack of correlation in adjustments —thus, the nervous system acting quickly in a fall, calls

for an over-tension of the muscles, which, jerking hard upon their attachments, snap one of the bones to which they are attached. Surgeons hold that the long bones of the body are broken by such muscular pull more often than by direct blows or crushes. The child and the drunken man often escape uninjured where the adult athlete is hurt; sometimes, at least, because of the lack in the child and the drunken man of this nervous over-tension, which leaves the muscles soft so that the bones escape fracture. Notice that Nature, left alone, does not often over-adjust, to a harmful extent. It is the human mind that interferes with Nature's automatisms far too often. The somnambulist walks safely along the fencetop—until he wakes! If one intends to consciously supervise his own adjustments one must be very sure one's conscious mind is well-equipped for the task.

This very sketchy outline of our adjustments to physical and mechanical forces is suggestive merely. It may be developed *ad libitum* by anyone. But it forms a very perfect introduction to the discussion of those chemical adjustments to the chemical poisons derived from plants and animals, especially to those derived from germs. This chemical adjustment when perfected is called immunity.

Immunity to Non-Bacterial Poisons

It is well known to nearly everyone that morphin, the product of the opium poppy, a plant poison, very fatal in small doses to the unaccustomed user, may, by gradually increasing the dose, become no longer a fatal poison but an actual necessity in large quantities daily. That this ability, this faculty which the body has of "getting-used-to-it" exists for very many things, usually poisons, but also some of them foods, is well known and needs no further elaboration here, except to point out the similarity of the process in this chemical field to that already described in the physi-

cal and mechanical fields—since "getting-used-to-it" requires slow, gradual, exposure with intervals of rest.

Chemical Injury

To illustrate, take the now familiar case of diphtheria. The healthy child, invaded by the much lower species of living protoplasm, the diphtheria germ, in the pursuit by the latter of food for itself, attempts to adjust himself chemically to the poisons of the latter. If the diphtheria germs are numerous, their poisons strong and abundant, the child's body, attempting this chemical adjustment, suffers extremely but perhaps slowly achieves the adjustment, neutralizes the chemical poisons and returns to health. A second attack by the diphtheria germ in the same child, shortly after, encounters now an adjustment already developed, already in working order, so that the adjustment is made this second time promptly and well—*i.e.,* without pain or damage. We say the child is "immune" or "not susceptible" to the diphtheria germ now, as he was at first.

But if on the first encounter of the child with the diphtheria germ, the latter be few in number, low in virulence, their poisons small in quantity and not very strong, it is possible for the child's body to make the chemical antidotes at a rate, which, inadequate to meet the situation outlined in the first instance, is able to meet the much slower and less serious situation now assumed. Hence the adjustment is without as much pain or damage; and in the end may achieve an equal protection to that achieved through the extreme pain and damage of the first quoted instance.

CHAPTER XI

IMMUNITY TO DISEASE

Immunity to disease is that part of Protection which deals specifically with chemical adjustment of the body to the poisons of germ diseases. Like the other adjustments already discussed to temperature, gravity, physical violence, it is available to us only within limits. It is probably as impossible to secure a body-immunity to, say, smallpox that will resist an immense amount of smallpox poison as it would be to secure an adjustment of soles by running barefoot, so thick that no spike or knife would cut them. Nevertheless, as bare feet may be hardened to stand all the ordinary demands of ordinary life, so various immunities to various diseases may be achieved sufficient to protect the body against all probable doses of those particular diseases.

Again, there are diseases against which practical immunity cannot be obtained just as no one can secure an immunity to being drowned. Some of our adjustments to our surroundings do not permit practical expansion. One may, it is true, by practice learn to remain under water twice as long as ordinary, but twice as long is still so short a time as to be practically of little value. Then there seems to be no immunity to some diseases, just as one cannot immunize any human body against high-power bullets. Such invariably fatal diseases are few, but exist, as tuberculous meningitis and systemic anthrax. Curiously enough also there are certain very mild diseases, notably the common cold (or colds) against which immunity is

not known. It is difficult to explain either the onset or the recovery from "colds" except by considering the onset as due to great multiplication, the recovery as due to diminution, of the germs concerned—results due in both cases to local conditions, not to systematic susceptibility or immunity. This is but a partial and speculative explanation at best.

Still again, chemical immunity to disease appears analogous to that obtained by usage in other adjustments, in that it is extremely specific. Adjustment of the body to heat must be developed by exposure to heat—adjustment to cold by exposure to cold; so adjustment to morphin cannot be had by taking anything but morphin, any more than adjustments to digging can be secured by rowing or to swimming by walking; just so also an immunity to smallpox can be secured only by suffering the smallpox poison, either as an attack of the disease or through vaccination; conversely, immunity to scarlet fever protects against scarlet fever but against no other disease and so on. The use of antitoxin or other antidotes in treatment of, *e.g.,* diphtheria, tetanus, botulism, pneumonia of type I, may seem at first an exception to this rule but those antitoxins, etc., are themselves formed in the bodies of lower animals (usually horses) by the administration of the corresponding poison to the animal. He then makes the antidote in response to the poison: and it is this antidote thus made which is administered to the human patient. Such antidotes are merely the ready-made or second-hand material which the patient must otherwise make for himself if he is to recover. Inasmuch, however, as he may also fail to make it and die; or make it too slowly or in quantities too small to prevent the occurrence of much damage before enough is made, modern therapeutics forestalls these failures on the patient's part by supplying him with the antidote from another source.

Active Immunity

Since the securing of immunity to disease requires that the person who is to become immune shall receive the poison of the disease into his body in some form, if he is to make the immunizing antidote for it, and since there are several distinct processes by which the poison may be received, there are several distinct corresponding ways in which immunity may be obtained. The immunity derived thus—by the person concerned making the antidote in his body, in response to the poison entering his own body—is called active immunity. The first and longest known, most obvious way is that in which the individual suffers an attack of the disease itself, as in suffering smallpox, chickenpox, scarlet fever, measles, German measles, Duke's disease, whooping cough, typhoid fever, paratyphoid fever, and some others. It has long been noted that those who recover from these diseases are thereafter immune; in most of the above cases for life, but in typhoid and paratyphoid fever for perhaps two or three years. Immunity thus obtained is obtained at more or less risk of death, and always after varying degrees of suffering, privation and expense; while the person affected is also during the process infectious and so a danger to all non-immune associates. Immunizing children against measles by the method of having the disease costs North America in the case of measles 12,000 children annually—*i. e.,* the children who die in the process; those thus immunized against smallpox are of course only the *survivors* of the total who suffer smallpox; usually in severe smallpox one-fourth those affected die; as many as one-third of those attacked died in the course of this disease in one recent outbreak (Glasgow). In Windsor, Ontario, 1924, *eighty per cent* of those attacked by the severe form died. The twenty per cent who recovered had been vaccinated at some

time, although not within eleven years. Those vaccinated within eleven years escaped entirely. We at once may conclude that the losses in this process of achieving immunity are appalling and that immunity thus achieved is far too expensive in every way for acceptance as a solution for prevention of disease in the race; although it has many thoughtless advocates who insist on it as "Nature's way." It is only *one* of Nature's ways—but the most expensive and damaging way, to human life and happiness.

Hence many experiments have been performed to secure active immunity by the use of the poisons of disease modified in some way so that the features of suffering and death may be eliminated, while the feature of immunity is obtained. Thus arose vaccination against smallpox in which the presumed smallpox germ is modified by passage through a cow and then used to give to the person who desires immunity a very mild attack of smallpox (called vaccinia); this mild disease threatening neither the individual's life or health, nor those of his associates, since it is not communicable except by direct inoculation. It is true that the immunity thus achieved is less permanent than that conferred by an attack of the disease of smallpox itself. Vaccination immunizes completely for only five to seven years; partially for a much longer period, perhaps as much longer on the average. This partial immunity differs from the complete in that the former may not prevent an attack entirely but makes any such attack mild and relatively harmless, while the latter, of course, prevents any attack at all. Nevertheless, the repetition of vaccination every seven years is a trivial price to pay as compared with the risk of dying or surviving only with permanent damage involved in suffering smallpox itself.

How or why the smallpox "germ" inoculated into a cow is so modified that when transferred from the cow to the human, its virulence is largely lost although its ability to elicit immunity remains, we do not know.

A similar modification of the poison is achieved in the case of rabies by a quite different method worked out by the great bacteriologist, Louis Pasteur. In rabies, the presumed "germ" is transferred from a "mad dog" to a rabbit, and when the rabbit succumbs, to still another rabbit, and so on, until the poison, instead of being weakened for the human, as in the case of smallpox, becomes immensely virulent. But it is not used in this form. The rabbit's spinal cord, in which this highly virulent poison becomes concentrated, is dried, thus weakening the germ again, until it does not hurt the human into which it is inoculated but does produce some immunity. More rabbit's cord, dried for a shorter period, and hence more poisonous is now given to this partially immune person; he promptly makes still more of the antidote to the poison and may then receive safely the rabbit's cord dried for a still shorter period. By continuing this process for two or three weeks, the person inoculated builds up an immunity so great that finally even the most virulent cord, dried for but a day, will not hurt him. Had he received this same cord as his first dose, he would certainly have died. Since a person bitten by a mad dog rarely develops the disease until three weeks later, prompt inoculation as above with the dried rabbit's cord will immunize him fully before the disease develops.

Again, in anthrax in animals, an immunity may be achieved by the use of anthrax germs, modified this time by growth at a high temperature in the incubator, a temperature high enough to injure the germs but not high enough to kill them or prevent growth.

In these three instances the *living germ,* modified, in the various ways described is used to supply the poison, in order that the body, inoculated with this poison, may produce the antidotes to it. Another way of securing immunity without suffering the disease is by using germs which have been not merely modified, but killed outright,

without, however, destroying their poisons. Thus inoculation of the person desiring immunity with these dead germs furnishes him the poison to which his body may react and so produce the antidote required to give him immunity. Dead germs are used for this purpose in securing protection against typhoid fever, paratyphoid fever (a & b), cholera, and a host of other infections due to staphylococci, streptococci, etc. These dead germs, thus used, are known as *vaccines.* Note here that while the word vaccination was used for the anti-smallpox treatment above described (being derived from the Latin word *vacca,* a cow) and the word vaccine is still used to indicate the material containing the living but modified smallpox germ obtained from the cow for inoculation into the human, yet modern usage condemns the use of the term *vaccines* for living germs, and urges the employment of "vaccine" only for dead germs, when employed for immunizing; using 'virus" for the living germ, as found in smallpox "vaccine," in dried rabbit's cord, in heat-modified anthrax cultures, etc.

The reasons why dead germs instead of live ones are used in vaccines is simply that dead germs are safer: they cannot multiply as living germs might. Why not then use dead germs in the previous instances quoted, for protection against smallpox, for rabies, etc.? Simply because in these instances the materials found in the dead germs are not capable (as they are in "dead" typhoid germs and other vaccines) of inducing the body to produce the needed antidotes. In the typhoid germ, the staphylococci, streptococci, etc., the poisons are formed in the bodies of the germs and are insoluble in water; they therefore do not escape from the cell body during life and are known as endotoxins. Only when these germs are killed and disintegrate do the poisons escape. According to Vaughan, the poisons do not even exist ready formed in the germ but the poisonous effects are due to its own

living substance, after disintegration of the germ cell. These body substances, according to Vaughan—the bacterial "proteins"—split up after death, and the split-proteins are poisonous. This distinction does not, however, affect the main issue, which is that in this group of germs, from which vaccines are made, the poison is available only in the dead germ, and to secure the poison, the dead germ must therefore be used.

In still another group of diseases (diphtheria, tetanus, botulism) neither the living germ modified nor the dead germ need be used. These respective causative germs produce *soluble* poisons during life. Hence, while growing outside the body in a test tube or flask of broth, as well as when growing in the body, these soluble poisons (exotoxins) diffuse into the broth from the living cell bodies, in marked contrast to the insoluble, non-diffusible poisons of the typhoid group. In this exotoxin group (diphtheria, teatnus, etc.), it is possible to grow these germs in broth for a time, filter the germs out by passing the broth through filters made of unglazed porcelain or of similar very fine material and thus secure the toxin (in the broth) quite separate from the germs (left stranded upon the filtering material).

Why is this done? Because it can be—because we thus are able to use the poison in its purest form, apart from the protoplasm of the germ-bodies. We cannot use this system, as we would if we could, in the case of the typhoid and other similar germs, simply because their poisons, not being soluble, would not be found in the clear filtered broth, as in the case of diphtheria, but would be left behind upon the filtering material with, or in the bodies of, the germs themselves.

To recapitulate these chief ways in which immunity may be secured: 1. *By suffering the disease,* as in measles. The poison reaches the body in its "natural" form, as the product of those germs which have been

transferred in Nature from a previously infected person or animal; and then acts in the new victim to produce an attack of disease, *i.e.*, produces an attempt on the part of an unprepared body to adjust itself suddenly to a very great qualitative change in its surroundings; no less a change than the meeting for the first time of a highly poisonous attacker, of which it has had no experience before. Some bodies fail to meet such attacks and therefore die. Others succeed in making the antidote in time to recover, having suffered great distress meantime in the process; but being thereafter immune to further attacks.

2. *By inoculation with a virus* as in smallpox. The person receives into his body a modified but *living* germ capable of producing the poison but in slight amounts or in weakened form; as in vaccination against smallpox.

3. *By inoculation with a vaccine,* as in typhoid fever. The person receives into his body the *dead* germ, containing the essential poisons. The dead germs may be counted and the "dose" thus controlled as accurately as in the case of any drug.

4. *By inoculation with a toxin,* as in diphtheria. The toxin is the poison of the germ separated from the germ by filtration. This toxin-inoculation is the process applied to the horse. When he has made the antidote (antitoxin) in sufficient quantity, his blood is drawn off, coagulated, and the antitoxin is found to exist in the serum. If now this antitoxin be administered to a human or any animal suffering from diphtheria, it supplies the antitoxin ready made, relieving the patient of the need to make his own.

Of late years, toxin, combined with some anti-toxin, has been given direct to the human, in advance of infection, to produce an active immunity in the human.

5. *By small "natural" doses of germs,* derived from other persons, exactly as in the ordinary process of contracting a disease. Recently it has been deduced that

in Nature, germs transferred as in No. 1 from a previously infected person or animal to a new individual may be sometimes transferred in such small numbers, or may experience such vicissitudes *en route,* or may have such difficulty in establishing themselves in the body which they reach, that they fail to produce poison enough to give symptoms of the disease, yet produce enough poison to elicit some immunity from the body. If a second, somewhat larger dose follows, and perhaps later a third or fourth still larger, this immunity production is continued; and at last perhaps the person thus becomes immune to any dose he is at all likely to encounter in Nature. It seems that this process of immunization, carried on by Nature accidentally, and discovered by man accidentally—this slow, gradually increased exposure with intervals of rest—is the explanation of the high percentage of immunity to diphtheria among adults as compared with children, which exists, notwithstanding that relatively few adults have had recognizable attacks of diphtheria at any time. It is true that a high percentage of immunity to measles amongst adults as compared with children also exists, but enquiry will show that, in contrast to the adults immune to *diphtheria,* the adults immune to *measles* acquired their immunity by suffering the fully developed attack; so that we do not require to suppose that they obtained it from a series of small doses of measles. The immunity thus achieved in Nature without the usual accompaniment of disease is called "immunity by small doses" for lack of a better term.

All the above described immunities, except that obtained by the use of antitoxin derived from a horse, are examples of active immunity; that is, the result of the active opposition of the body itself to the poison, with the resultant formation of the antidotes to the poison. The immunity obtained by the use of the antitoxin derived from and therefore made by a body other than the

one in which it is used (horse antitoxin, injected into a human patient) is known as *passive* immunity, since no active operation is undertaken in the body of the person receiving the antitoxin—it merely accepts the ready formed antitoxin, which then attacks the poison.

All the immunities so far described, both active and passive, are immunities obviously achieved by the living body after it appeared in the world, and are known, therefore, as *acquired immunities.* Such persons were, when born, susceptible to the various diseases to which they afterwards became immune, to which they acquired immunity. But some persons are born immune, and therefore do not require to achieve immunity thereafter. Thus in a few instances, the fetus may acquire immunity *in utero,* from an attack suffered before its birth, by the mother. Children have been born pock-marked as the result of smallpox suffered *in utero* from which they had recovered before birth. Such children would of course, be immune to smallpox for life. The writer vaccinated a pregnant female who "took" well. The girl baby proved up to the age of 21 completely immune to some 30 vaccinations, attempted after birth, and in every instance gave the anaphylactic reaction for immunity such as is given on vaccinating persons who have previously had a successful take within five to seven years. She had therefore, through her mother, an intra-uterine immunity to vaccinia. Such intra-uterine immunities are acquired, although acquired before birth instead of afterwards. Acquired also is that curious immunity found in nursing babies to diphtheria, measles, and scarlet fever. It is supposed that provided the mother is immune, the child is immunized through the milk, since bottle-fed infants may not be immune to these diseases. But it is also true that mothers who contract diphtheria, measles, or scarlet fever may continue to nurse their babies without

the latter contracting the disease. Here we cannot assume previous immunization of the mother, for this is negatived by the fact that she has just contracted and is suffering from the disease herself. It has been assumed that antidotal bodies are supplied in the milk at an early stage in the disease in the mother, in quantity sufficient to immunize the child in advance of or synchronously with the infection it is practically certain to receive when it continues in its sick mother's arms. In scarlet fever the incubation period is in general five days, and the patient is not infective during this stage. If now antidotal bodies are formed during incubation and passed out in the milk also at this time, it is not difficult to assume that the child is thus immunized before it is infected or at least before it develops the disease, *i.e.*, during its own five days' incubation. In measles, the chances for immunization during incubation are even better, for the incubation period averages ten days, during which the patient is non-infectious; and therefore the child is nursing for a total of twenty days after the mother is first infected, before infection conveyed by her to her baby could produce symptoms. But in diphtheria the incubation period is not only very short (a day or so at most) but the mother is necessarily infective during this stage as well as later, although probably to a lesser extent. In all three cases, moreover, the hypothetical antitoxin in the milk is not injected as our antitoxic sera are, into the child's body, but is taken by the mouth, a method of administering antitoxin which would be doomed to failure in the older child. It is therefore not clear just how or why or when the nursing baby becomes immune to these three diseases—and still less why it is not immune, under parallel conditions, to whooping cough, syphilis, tuberculosis or other affections.

Inherited Immunity

Besides these acquired forms of immunity, children are sometimes born with immunity to some disease, while remaining as susceptible to others as any one else. Almost every one is acquainted with instances where, under identical exposure, one or more children in a family escape and the others contract a disease. Sometimes this is a case not of immunity but of non-infection, as is shown by the supposedly immune person's contracting the disease as a result of later exposure and infection. Yet there are undoubtedly some instances of these peculiar or "freak" immunities, particularly in tuberculosis. The writer encountered a healthy and intelligent man of forty, the *only* survivor of a family of seven children, all the others having died of tuberculosis at early ages. He was one of the middle children, not the youngest nor the oldest. Two hours' friendly and intelligently coöperative cross-examination failed to bring out a single item in which his birth, upbringing, schooling, associates, food, drink, sleep, dress, sleeping quarters, exposure to infection, or any other conceivable or inconceivable factor of his life, differed from those of his brothers and sisters. There was nothing left to explain his escape except hereditary immunity.

How account for such immunity, or indeed, immunity of any kind? According to the principle that immunity is adjustment, the immunized living protoplasm must have had previously the ability to make the required adjustment; true, the adjustment is not made until the demand calls for it, but there must have existed a potentiality for adjustment or the protoplasm could not have responded. Most people are born with potentialities for adjustments to heat, to cold, to rapid motion, to a great variety of foods and to innumerable other circumstances

and conditions. But some people are, for instance, born blind and therefore can never adjust themselves or their eyes to light or to distance; others are born albinos and although they have eyes and can see, yet cannot "stand" strong light, that is, they have less adjusting abilities for strong light than most people have. Obviously a person born without arms cannot make all the adjustments possible to one not similarly handicapped. But one who has arms may not succeed in acquiring the adjustments, say, necessary to swim, to write, to use a typewriter, to juggle. Nevertheless, he has the potentialities for all of these as the armless person has not. Nearly all of us are born with the ability to assimilate strawberries and eggs, but there are some persons who lack these particular potentialities for adjustment to such a degree that strawberries or eggs are to them real poisons. (See anaphylaxis.) In such instances, if no potentiality at all exists for, say, strawberries, then the upset, rash, and other disorders which follow the partaking of strawberries, cannot be overcome; but if some potentiality, however small, exists, a prolonged course of strawberry eating, beginning with infinitestimal quantities and increasing them gradually, with intervals of rest, will develop the potentiality until the patient is at last adjusted, or in other words, has become immune and may eat strawberries as freely as anyone else does. Even those who at birth have good ordinary potentialities for adjustment to strawberries are brought to the immunity point unconsciously during childhood generally, by means of "small doses" of strawberries. Just so with milk, eggs, and very many other foods. So far as is known, it is always the protein of the food which acts as a poison; that is, it is to the protein of the food that we fail to adjust.

We may therefore look upon the poisons of the germs of various diseases as merely items in a vast series of chemical bodies derived from the protein of living things.

The usefulness or the poisonousness of a given item of this protein or protein-derived series depends less on its own intrinsic character than on whether we have an adjustment for it; that is, whether or not we have the ability to make a chemical combination with it which is neutral or useful to us instead of poisonous. To some chemical derivatives, as those of the strawberry, the cow, the hen, most people have the chemical adjustments well developed; only a few have not. To other chemical derivatives, as those of the typhoid "plant," the syphilis "animal," the diphtheria "mycobacterium," most people are not so adjusted as to escape ill effects from a relatively large dose, although a few are. Nevertheless most of us have some *potentiality* for adjustment to the chemical derivatives of these disease germs, especially those of typhoid and diphtheria; hence we can manage small doses without obvious ill effects and by repeating such doses at intervals we may develop our potentialities until at last we can manage large doses successfully; that is, until we are immune.

Of what character the chemical bodies are which thus make us immune or potentially immune to strawberries—or to typhoid—is hard to say, and still harder to guess for what purpose they originally existed. Seemingly, the average human body at birth is stocked like an apothecary's shop with larger or smaller samples of a vast variety of chemical bodies, each capable of uniting with and rendering harmless or even useful some one of the almost innumerable proteins or protein derivatives in the living things of the external world. We know surely that the human body generally responds to a temporary acute demand made for any one of these special chemical bodies, by manufacturing that body in excess, much as a druggist, called on at last for some drug that has for years stood idle on his shelf, might "scent a demand" for it and make a lot more at once.

Thus, the presence of the diphtheria or the typhoid

poison in the body creates the demand for the corresponding neutralizing agents. Substitutes will not do. The most complete "line" of antidotes to diphtheria will not in the slightest degree meet a demand for antidotes to typhoid, and vice versa. The body must produce the specially required antidote or else perish. In the case of diphtheria, the body may literally and metaphorically obtain a ready-made stock from a wholesaler, instead of making the antidote itself; that is, the body may be supplied with antitoxin from a "wholesale warehouse," the body of an immunized horse. In the case of typhoid, however, this ordering in from outside is not possible at present; the body itself must produce the antitoxin; either during the attack, in response to the poisons "naturally" acquired; or previous to the attack, in response to dead germs purposely inoculated.

"Freak" immunities, like that of the sole surviving member of a tuberculous family, may be explained by supposing that although nearly every one at birth has a good stock of samples of all the antidotal chemical bodies he may need later, yet just as people vary from one another quantitatively in every physical detail—one has larger or smaller ears than another, or larger or smaller feet, or brown eyes of lighter or darker shade—so also in details of chemical equipment they vary quantitatively. A person may be born with quite the ordinary amount of most of these "samples" yet with more than the usual amount of one, say the sample antidotal to scarlet fever,—and less than the usual amount of, for instance, the sample antidotal to diphtheria. Such a person would be more than usually insusceptible to scarlet fever, less than usually insusceptible to diphtheria.

At all events, it is well known that a child may recover from scarlet fever quite readily and later succumb to diphtheria and vice versa. Multiply this example by hundreds of thousands relating to all sorts of diseases and

we are justified in assuming that the initial stock of antidotes and the ability to make more of a special antidote on demand, vary in different individuals quantitatively just as other items of our make-up vary, as, for instance, the length of our bones, the shade of our hair. Also, they vary for the same reasons,—the peculiar quantitative combinations of the hereditary equipment handed down to us from our much mixed ancestry.

Racial Immunity

A disease introduced among a group of people who never encountered it before meets with but a scanty supply of antibodies. Tuberculosis is said to have killed one in every four people in Europe in the Middle Ages; now it kills only one in twelve. Among eleven thousand Sudanese brought into France by the British during the Great War, the number of deaths from tuberculosis greatly exceeded those among the three or four million British troops. The Sudanese had not been exposed to tuberculosis until they came to France; the British have been exposed to it for many generations. To resume a previous simile, the Sudanese of today are in the position that the British were in the Middle Ages. They resemble a series of drugstores which have indeed carried small irregular stocks of a drug which, however, has been hitherto uncalled for. When the demand appears, those few stores which happen to possess a sizable amount and the ability to make more, survive; the others, the vast majority, go out of business. The relatively few survivors transmit to their successors the secret of making and stocking this drug. The others have no successors!

Hence, the British of the Middle Ages who could and did manufacture immunity bodies against tuberculosis, had a chance to survive, to have descendants, and to trans-

mit this ability to their descendants. Those who had no potentiality or who had no ability to develop their potentiality died of tuberculosis and therefore had no descendants to whom to transmit their lack of ability. Gradually, by elimination of the relatively non-immune, the population would come to consist only of families, or 'strains," which had the greater potentiality for immunity. Although this indicates the principle, its results would not be quite so clean-cut as thus indicated, because some of the non-immunes might live long enough to have children, to whom they might transmit their lack of resistance. Moreover, some persons of high immunity might marry persons of low immunity and thus split their children's immunity proportionately, according to Mendelian principles. But slowly, incoördinately, uncertainly, yet in the long run, effectively, the survivors would tend to be those of high immunity; and in time the surviving strains would be those which possessed immunity rather than those which lacked it. Doubtless, in the course of many generations a similar work-out will be observed among the Sudanese, and, perhaps in time, they will develop a partial immunity similar to that possessed by the British now.

It is to be noted that it is the fatal diseases, not the non-fatal, that tend to produce racial immunity by this method; and these produce it more quickly when they attack the younger rather than the older people. However, no race of humans is known which has complete insusceptibility to any one human disease. Such complete insusceptibility could not on the above hypothesis be attained except from diseases which invariably attack their human victims before the child-bearing age, and invariably kill. Practically no infectious disease can reach all its victims while they are children. Therefore at least in isolated communities there would always be some adults who had never been exposed, and some at least of whom would

therefore be non-immune and so would transmit their non-immunity to their children.

On the other hand, *acquired immunity,* unlike *hereditary immunity,* cannot be transmitted to descendants. Almost every one of us today must have among our ancestors many who had smallpox, yet we are not immune to it. Again we have lines of ancestors nearly every one of whom had measles, *and as a rule had it when children.* Yet their acquired immunity has not been transmitted to us in the slightest degree, for ninety-five per cent of those born today are just as susceptible to measles infection as their ancestors were, catching it usually at their very first opportunity.

The stories of tribes wiped out, adult and child, by measles when first introduced among them, seem to negative this statement. But Newsholme, who has specially studied the South Seas outbreak so often quoted in support of the transmission of acquired immunity, attributes the high death rate from measles among the natives, to the extraordinary treatments given by the natives in the panic which developed. He states that among the natives, *who were treated by white physicians,* fatality was not more common than among Europeans, and this regardless of whether the patients were adults or children. (Personal communication from Newsholme.)

It need hardly be pointed out that Nature's methods of developing the partial race immunities which now exist are exceedingly slow and uncertain, requiring many generations in time and enormous expenditures in human life, pain, sorrow, and economic loss. On the other hand, immunity acquired by more or less artificial but more immediate and direct means, such as vaccination, makes at once available to all of us a protection that Nature in its slow progress would provide for only some of our descendants, perhaps a thousand years hence.

Racial Susceptibility

Much has been made of the fact that certain groups show a higher incidence of certain diseases than do other groups. Thus, for instance, the Irish have tuberculosis much more than, say, the Italians; and therefore some would say that the Irish are more susceptible to this disease. It is hard to see just how such a statement would differ from one designating the Italians as more immune than the Irish. Leaving aside the question of terms, however, it certainly is conceivable that as some groups have chiefly blue eyes, others brown, so some groups may relatively lack while others may possess a relative excess of the average ability to make immune bodies. But if we take into account the explanation of immunity already given, it is easy to see that the *opportunity for infection* is as important a factor in the problem as is the potentiality to make antibodies. The fatality of the disease and its incidence before or after the child-bearing period are also important factors. Sociological habits also play a part. For instance, the custom of early marriage would mean more non-immune parents, but under a late-marriage régime more non-immunes would have succumbed before marriage, leaving a larger proportion of immune survivors to carry on the race.

Many false theories have been current in regard to racial immunity, such as that which assumed that all West African negroes were racially immune to yellow fever. It is true that *adult* negroes who accompanied European adult whites into yellow fever districts did not contract the disease, although the percentage of fatalities from it among the whites was very high. However, later investigations showed that the immunity of the adult negroes was not racial but acquired. The fact was that they had had yellow fever in childhood and had thus be-

come immune. The whites, of course, had lived in Europe as children and had not been exposed to the disease until later life. If we as adults today were to visit Mars, the Martians might consider us racially immune to measles, if the disease is known to them, since few or none of us would contract it there; but we ourselves would know only too well that our adult immunity to measles was painfully acquired in our own persons in childhood by suffering the disease.

The question of human racial immunity and susceptibility is by no means satisfactorily solved. There is no such thing as a clean-cut racial immunity or a clean-cut racial susceptibility, to the extent that no one of a certain race ever contracts a certain disease on exposure, or that every one of a certain race always succumbs to a certain disease on exposure. On the contrary, the facts are that in the absence of acquired immunity, there is no human race some of whose members may not contract any known human disease if exposed to it, and there is no human race some of whose members may not escape any known human disease despite exposure. True, the percentages in which different races may and do contract or escape certain diseases, vary, but that is all; and *opportunity for infection* must always be considered in the summation of evidence relating to incidence. Thus eighteen years ago, in Minnesota and Ontario, typhoid fever was ten times as prevalent as it is today. There can have been no change in racial susceptibility in that period. Moreover, Minnesota has a most mixed population,—Norse, German, Southern European,—while Ontario has in large proportion exclusively Scotch, Irish, and English. The fact in both localities is this: fifteen years ago both had much typhoid *because both had had much typhoid before;* that is, because many persons had had it, and many others were exposed to infection from them. But as gradually in some localities Public Health effort lessened the number of cases,

it lessened likewise the number of possible sources of infection, that is, of persons infected and able to give the infection to others. There is comparatively little typhoid now either in Minnesota or in Ontario, not because of insusceptibility, but because there are fewer infected persons to impart infection to others. Failure to note this factor is the basis of Raymond Pearl's fallacies regarding hereditary tuberculosis.

So far as opportunities for infection control the question, the more of a given infectious disease there is in a given race, the more there is likely to be; the less of it there is, the less there is likely to be.

Species Immunity

All this is in strong contrast to the variations of immunity existing in different *species* as distinguished from different races of the same species. It is in strong contrast also to the racial immunity found among some of the lower animals. Thus, smallpox, chickenpox, measles, and some other human diseases, are seldom if ever found in recognizable form among other *species,* no matter how close their resemblance to man. It is true that the "cowpox" of bovines is a modified form of human smallpox, doubtless contracted by the cow from the human; but it is so much modified in its symptoms that up to about a century and a half ago their relationship was not detected. Among sheep, which as a species are very susceptible to anthrax, one *race,* the Algerian sheep, is immune to this disease. In general, each species of animal has a set of diseases, some of which it shares in common with other species and some of which are peculiar to itself. This is especially true of disease caused by the very small microscopic germs. Disease due to protozoa carried by the larger parasites both in man and in other animals, are usually very closely confined to one genus only. For instance, the yellow fever

germ and the malaria germ each infects but one genus of mosquito—anopheles and stegomyia, respectively—and these germs can be effectively transmitted only to man, though infected mosquitoes of these genera often bite other species of animals. Other germs, similar to, but not identical with, those of malaria infect another genus of mosquito and can be transmitted by this mosquito to crows but will not infect any other animal, nor will any other genus of mosquito infect the crow with these germs.

Mechanism of Immunity

In what way do the antidotes or antibodies act that are prepared by the body to neutralize or destroy the various poisons of disease?

In diphtheria, tetanus, botulism, and some other diseases, we know from laboratory and clinical evidence that the antibodies produced by the attacked bodies are *chiefly* directed to neutralizing the poison of the germ and not to destroying the germ itself. For instance, when the antitoxin against diphtheria is obtained from a horse, diphtheria bacilli introduced into this antitoxin, even in its most concentrated form, grow freely in it. Hence, there is nothing in the antitoxin which opposes either their life or their growth. Yet antitoxin neutralizes the poisons that the diphtheria bacilli produce, as may be shown by inoculating one of two guinea pigs with the pure toxin or poison of these germs, in a dose sufficient to kill; and then inoculating the second guinea pig with the same or even a much larger amount of the same toxin with which a sufficient amount of antitoxin is mixed. The first guinea pig will succumb; the second will show no harmful effects whatever. Furthermore, if antitoxin is administered to the first guinea pig after it has been inoculated with the toxin, it also will survive without harm. Clearly then, diphtheria antitoxin is capable of neutral-

izing diphtheria antitoxin whether mixed with it in a test tube or in the body of the animal, but, as previously stated, it does not affect the life or the growth of the germ itself.

In another group of germs, including the typhoid and streptococci—the group from which vaccines are prepared because of the insolubility in water of their poisonous products—the body seems to make a variety of efforts against them. Some of these efforts aim at the destruction of the germ itself by means of substances known as *bacteriolysins,* which tend to break up and dissolve the germ; other efforts tend to throw the germs together in a conglomerate mass and prevent their movements by substances known as *agglutinins.* This reaction is not very definitely antidotal, for bacteria thus agglutinated continue to live, grow, and multiply even in the agglutinated mass, as may readily be observed under the microscope. We may perhaps look upon agglutination as an early step in a prolonged attack designed to end in the destruction of the germ; or as a sort of vestigial remnant of tactics which once seemed to promise well and though failing of their aim, were not discarded by the body.

The Adjustment of Germ to Human

With the adjustment of the body to the germ, there goes on at least some adjustment of the germ to the body. This is quite evident in those instances of humans known as *carriers.* These are persons who have had typhoid or at least an infection with the germs of typhoid and have become immune; though quite well, they retain the germ in their systems, sometimes for a long period. These germs no longer harm the carrier nor are they harmed by him. They remain ensconced in his throat or nose (diphtheria bacilli) in his intestine (typhoid bacilli and cholera spirilla) and there grow and flourish. They have

not lost their power to produce poisons although these poisons do not harm their host. That their poisons are still active is shown by the fact that if they are transferred to other non-immune persons, they promptly produce the usual symptoms and may kill.

Not only is the carrier immune to the poisons of the germ he carries, but evidently the germs are also immune to his, so far as these poisons reach them. This situation has been described as a *victory for the individual* but a *defeat for humanity;* for the individual human carrier has conquered the hostile germs he carries himself but he may distribute them to other humans not so fortunately armed against them as he is. Thus he may and often does spread disease and death among his associates over a period of years, thus doing more harm than fifteen or twenty ordinary cases of the disease itself whose period of danger to others is but a month or so.

In the long run, however, this adjustment of the germ and the human to each other may be the natural outcome in all disease. One may imagine a community in which all the members are carriers of typhoid bacilli. All are infected and infective, yet all are also immune and therefore germs transmitted from one to another will do no harm. It is not impossible that the colon bacilli, so universal in the human intestine now, may at one time have been as rare as the typhoid bacillus is today, and may at that time have been, as typhoid is now, a producer of disease. It is not therefore impossible that we are all "immune carriers" of this germ which therefore hurts no one.

Tolerance

Tolerance is a variety of immunity which persists only so long as an active demand for it continues. The immunities so far described as that to smallpox, typhoid,

diphtheria, persists after the germs have disappeared for periods varying from a year or two in the case of diphtheria and typhoid, up to the end of a long life in the case of smallpox and chickenpox. The adjustment made to these poisons remains therefore long after the poison itself, has disappeared, and therefore with it the active demand for the antidote. On the contrary, in malaria, probably in syphilis, and perhaps in tuberculosis, the immunity developed in the presence of the poison disappears when the living germ does; in other words, when the immediate demand ceases, the supply fails also. The difference between immunity and tolerance means that a person who has wholly recovered from such a disease as smallpox, chickenpox, typhoid, remains nevertheless immune; but one who has wholly recovered from malaria, syphilis, tuberculosis, to the extent that the germs have disappeared from his body, is *liable to contract the disease all over again.*

Summary

Broadly speaking, *immunity* is a state of adjustment, which, while it lasts, obviates that partial unsuccessful adjustment which because of the pain or damage resulting constitutes disease. Where an ability for adjustment does not already exist, and the potentiality does, it may be achieved on the development of demand for it, *and only so.* If the demand be made gradually, slowly, with intervals of rest, the adjustment may take place without pain or damage, that is, without disease. If in response to a sudden and strenuous demand, adjustment is attempted abruptly, rapidly, and without intervals of rest, the attempt may fail, or if ultimately successful, its progress is accompanied by pain, damage, and strain constituting *disease* at the moment; perhaps involving prolonged disability afterward. Once achieved, however, the adjustment tends to persist in some cases, and in others, to be

readily recovered if lost. Immunity to germ diseases is therefore but an instance of the achievement of one form of those adjusting abilities which are possessed by all living things and without which they could not live at all.

Disease, in those instances at least where we know the cause, is merely the struggle for adjustment when it is painful or damaging. The ability to adjust at all is hereditary, a part of the necessary endowment of living protoplasm, for without it protoplasm would speedily die. A human being inherits thousands of adjusting abilities; the absence or small amount of any particular one of these abilities will not harm him unless and until a demand arises for that particular adjustment. When disease occurs, its outcome, whether death or recovery, with or without damage, depends on the existence of a potentiality for adjustment and on the ability to develop the potentialty unless, as in the case of diphtheria, the results of the well developed adjusting ability of some other being are available.

Non-Relation of High Health, Physique, Etc., to Immunity

In discussing immunity to disease, it is necessary to comment on one curious and widespread but most fallacious doctrine, which quite inverts the facts as we know them, appearing to make immunity a product of health instead of the converse. Health is a state of adjustment to the demands of the moment. If amongst those demands is one from the presence of a disease poison, and if the body can meet that demand, health, *i.e.*, adjustment obtains, and neither pain nor damage ensue. This particular class of adjustments, *i.e.*, to disease poisons, we call immunity. If the body is not adjusted to the particular demand made, pain and damage result, *i.e.*, disease. Such a body we

say is non-immune. Hence, so far as disease-poisons go, *health is a product of immunity, not a cause of it.*

Now, how is immunity obtained? Turn back to the chapter on this subject, to any book on immunity, to the facts known to every physician and to most laymen, and see for yourself. Apart from the "artificial" immunities, due to vaccinations of various kinds, and the occasional immunity conferred by small doses in Nature, we have the rare and usually partial immunities that are inherited, and the most common of all, those following an attack of the disease in question. Our most common diseases, suffered sooner or later by almost every one born into civilization, are chickenpox and measles. Nearly every one knows, by personal experience in their own bodies, that these diseases are usually contracted on the very first exposure to them, except that in the case of measles nursing babies escape. Let us take a common case—a healthy strong child, who reaches the age of six years in an isolated country home. Fresh air, good food, exercise, everything has combined, let us say, with a good initial physique, to make this youngster "the picture of health."

Now a friend comes to stay at the house, and the friend's child, who has been exposed at its home, comes down with measles while playing with our young six-year-old. Ten days later, the six-year-old has fever, red eyes, a slight cold, brassy bronchial cough, Koplik's spots, and in four days a measles rash. He becomes very sick indeed, almost dies, but in time pulls out, and is presently running about, as well as ever. He is different in one respect, however; even the hired help know, that now he has had measles, he won't get it again! In other words, he is immune. Was that immunity the result of his high health? The promptness with which he contracted the disease at the first moment he was exposed to it proves that he had no immunity, although six years of the highest health had preceded that date. Since that moment of ex-

posure, now four weeks ago, he has been in the worst physical condition that he ever has been in his life. Fever, headache, loss of appetite, delirium, bronchitis, emaciation—all but dead several times, let us say. He comes out of those four weeks of illness with something six years of health did not give him—*i.e.*, immunity. It was during the lowest state of vitality he ever passed through that his immunity developed, not while he was in health. This same account might be given again and again, changing the names of diseases, the symptoms, duration of the attack, etc., for every one of the diseases to which immunity may be had. How then has arisen the quite extraordinary idea, the converse of the truth, that health produces immunity? Since, if we take each disease that we know of by itself, this is not true, how can it be true, as it is usually stated, for all the diseases put together?

Immunity, then, is not merely unconnected with health; it is actually the product of disease, in the majority of cases. In all the remainder, except in inherited immunity, which is rare and usually incomplete, it is the product of exposure to the poison of disease, even though the actual pain and damage of the full-blossomed attack be averted by the various methods already enumerated. Even in passive immunity, the immunizing agent itself is the product of disease or exposure to disease, in a preceding case.

The justification for making so much of this absurd fallacy lies in the fact that, not only do commercial advertisers exploit it in order to sell their own systems of diet or exercise, which they claim ensure health and therefore, on the above misconception, immunity; but many lay propagandists for health have seized upon this fallacy and have preached it with fanatical fervor on every occasion. The motive in this latter instance is good, but the results are appalling. Enormous numbers of unfortunate persons, following these unfounded doctrines—

not doctrines indeed but mere dicta—have succumbed to smallpox because they trusted to the broken reed of high health, instead of to real immunity from exposure to the poison, in this instance, smallpox vaccine.

The influenza epidemic of 1918 converted many of these well-meaning but thoughtless and reckless propagandists. It was too obvious to every one that influenza took the strong and healthy between twenty and forty, and left the young, the old, and the tuberculous. Yet even today, and alas, even from professional health officers, one may occasionally hear the same man solemnly pronounce that the only protection against smallpox is vaccination, the only protection against typhoid is typhoid inoculation, and then add the contradictory statement that high health is the great preventive against infection, perhaps before the same audience, even on the same occasion.

The only instances in which poor health contributes to disease infection appear to be (a) where the poor health is the result of a previous infection with some other disease germ, notably in the instance of influenza, the presence of which appeared to make the subsequent infection with a streptococcus almost certain to result in serious illness, often death; and (b), where the other disease is so serious as to act on nutrition to an extreme extent.

The presence of such conditions appears to make infection of a non-immune person more easy than their absence. But even such conditions do *not do away with an immunity already established.*

The person immune to smallpox does not lose that immunity under any known set of circumstances, starvation, drunkenness, or other diseases. Only an overwhelming dose of infection will overcome his immunity, and it will do this whether he is in high health or not.

It is perhaps well to add here that no one, immune or not, can contract a disease to which they are not exposed.

If we steadily reduce the disease germs of the world, immunity to them will become less and less important. If there were no smallpox, why immunize against it? The methods of Hygiene against these infections are interesting and useful, but abolition of the disease germs will make all these immunities unnecessary. One does not need screens against mosquitoes where there are no mosquitoes!

CHAPTER XII

ANAPHYLAXIS

Since immunity is that state of the body in which it is when it has become *insusceptible* to a given poison, and since such a body is thereby fortified in advance against future attacks of the otherwise dangerous poison, such a body may be said to be in a *prophylactic state.* This immunity is the result of the action in the body of the given poison, in response to which action the body *armors itself* against that poison.

A converse condition exists in which the body has become *susceptible* to a heretofore harmless substance. It is therefore rendered open to future attacks of the otherwise harmless substance and is said to be in an *anaphylactic condition.* This kind of susceptibility is usually acquired; we do not generally possess it before birth as we do our natural susceptibility to disease poisons. In the case of the disease poison susceptibility is the usual situation at birth; it is the *immunity* that is acquired by the action of the disease poison in the body. But in anaphylaxis, it is immunity to the harmless substance that is natural; it is the *susceptibility* that is acquired by the action of the substance in the body. In the term anaphylaxis is embodied the idea that the body has *lost* its *armor* against the harmless substance.

Source of Anaphylaxis. All the harmless substances which in their action on the body contrast thus so strongly with the poisons of disease, are proteins—the natural proteins of species *other* than that to which the affected in-

dividual belongs. To take a classical instance, let a guinea pig be injected with a very small dose of horse serum (say, one one-hundred-thousandth of one c.c.). No immediate effect whatever is observable in any direction; nor will any effect develop later unless and until a second dose of horse serum be endured, *after* the lapse of an interval of about ten days, as a rule. Thereupon, typically, the guinea pig scratches its nose, coughs, passes urine and feces involuntarily, and dies in a minute or two. What has happened? The first minute quantity of horse serum, doing no harm when first given, has in some way during those ten days so affected the guinea pig's body that when a second dose is given at the end of that period, it causes death.

Note first that anaphylaxis, like immunity, is very specific. A guinea pig injected with horse-protein is sensitized to horse-protein and to horse-protein only. An injection of egg-proteins or of milk-protein, following horse-protein, would do no harm. But a guinea pig sensitized by a minute dose of egg-protein would succumb to a second dose of egg-protein given at the end of ten days, although he would not suffer at all from either horse-protein or milk-protein. Just as one immunized to scarlet fever is nevertheless just as susceptible as ever to any other disease, so the guinea pig made susceptible to horse-protein is still just as insusceptible as ever to other proteins.

Note further that when a disease poison enters the body of a human, *there elapses before immunity develops, an interval (incubation period), whose length varies with different diseases;* and conversely, when a harmless foreign protein enters the body of a guinea pig, *an interval approximating ten days elapses before susceptibility develops.* Furthermore, just as the state of immunity yields in itself no symptoms and therefore cannot be demonstrated except by the fact that the specific poison to which

the person is immune can enter his body without harm, so the state of anaphylaxis gives no symptoms and cannot be demonstrated otherwise than from the fact that when the specific protein to which the person is sensitized enters his body, that protein precipitates illness.

Striking and immensely interesting as they are, these anaphylactic states in the guinea pig would nevertheless be of little practical value to human hygiene, were it not that some apparently identical reactions and others similar, if not identical, are found in human bodies.

Human Sensitization. In view of the many forms in which the sera of other species are injected into the human in these days, it is fortunate that as a rule the *human is far less susceptible to anaphylaxis* than is the guinea pig, and that the circumstances and amounts in which sera are administered to the human are not those which most conduce to the development of anaphylaxis. Thus, guinea pigs, not injected with horse serum but merely kept in a stable where there are horses, may become *sensitized* to horse-proteins, by the inhalation of particles of horse epithelium, horse hairs, horse mouth spray, and from eating food on which these things have settled. The guinea pigs, thus sensitized by way of the alimentary tract instead of by injection, may succumb to an injection of horse serum subsequently given although that injection is the first injection that they have received. The sensitization by inhalation and other means has in this instance taken the place of the first injection in the experiment described above.

Parallel with these facts, we find that occasionally when humans receive an injection of horse serum—say a prophylactic dose of antitoxin—for the first time, they show *immediately* reactions of anaphylaxis. In such fortunately rare instances, we are forced to conclude that such persons have been sensitized by inhalation, through the alimentary tract, or in ways other than by injection as the

result of association with horses. Yet, the rarity of such an anaphylaxis in the human despite the abundant opportunity for it indicates that the human is not very susceptible to this form of sensitization. Again we have all used milk from infancy—human milk and cow's milk—yet few of us would succumb to a first injection of either kind of milk although instances of definite milk sensitization have been recorded. It is true, however, that comparatively mild reactions to common proteins are not uncommon. Many cases of asthma, of hives, of eczema or other skin eruptions, besides other affections hitherto obscure in origin, have been traced to sensitization by inhalation or through the alimentary tract of some one or more foreign proteins. Hay Fever is due in part to the introduction of the proteins of various pollens by one of these methods. In all these instances, a person once sensitized is subject to ill effects from subsequent doses received sometimes from obscure sources. Thus, asthma in a person sensitive to the proteins of goose feathers continued in spite of every effort to avoid geese, until it was found that the pillow used at night was stuffed with goose feathers; that on substituting a pillow of chicken feathers, the attacks ceased.

The objection will at once be raised that we are continually introducing foreign proteins into our bodies, that such introduction daily or more often is a fundamental need of nutrition in animal life, that animals cannot long survive without a constant stream of proteins derived from their own species or more often from other species and incorporated into their own systems, that by inhalation also we are continually taking in foreign proteins from plants and animals and in the form of dust with our foods; yet we do not suffer from them.

True, but there are two reasons why this stream of miscellaneous proteins so seldom produces sensitization in the human. One reason is qualitative, the other quanti-

tative. The *qualitative reason* is this: the proteins taken by inhalation as well as those taken in food seldom enter our bodies as protein. If they pass our noses and mouths successfully, most of them, whether inhaled or taken by mouth, are swallowed and so reach the stomach. But while there or in the intestines, they have not yet entered our bodies, properly speaking. They are still outside the body proper, as a finger in the hole of a doughnut is not really in the doughnut, that is, in its substance proper.

Material in the intestine must first pass through the intestinal wall in order to enter the body, just as material applied to the skin is not in the body until it passes through the skin. Now, proteins introduced into the stomach or intestines do not normally pass through the intestinal walls as proteins but as amino-acids, and amino-acids do not sensitize as proteins may. Only when protein passes as such through the skin or through the intestinal wall into the body proper can anaphylaxis result. It is clear enough that when proteins are injected with a hypodermic needle, they enter the body as proteins because they thus avoid the intestinal juices which would change them into amino-acids. It is of course also conceivable that proteins taken in by the nose or mouth might, through cuts or scratches of the nasal or oral or other mucous membranes, or possibly through old scars in the intestinal wall, have access to the blood stream before being swallowed and digested. Even after reaching the stomach or intestine, and even while undergoing digestion, it is conceivable that some of the protein escaping digestion might slip into the blood stream through abrasions of the mucous membrane or even through minute areas of chemically injured tissue.

However this may be, it is unquestionable that both sensitization in the first place and anaphylaxis later may be brought about by proteins entering the body apparently through the stomach or intestine; and that the evidences of passage by such routes occur too often to make it likely

that no extraordinary conditions of the mucous membrane existed at the time. On the whole it would seem that the danger of anaphylaxis from protein which reaches the blood stream is usually withstood safely; for instance, compare the small percentage of persons who develop hay fever with the total of those exposed to the causative pollens.

The second and *quantitative reason* why sensitization in the human is relatively rare is the fact that if the initial dose of a foreign protein be large rather than small sensitization is not so likely to occur. It will be remembered that the best dose of horse serum for sensitizing the guinea pig may be as small as one one-hundred-thousandth c.c. If instead of this small amount, one c.c. is administered, sensitization may be slight or may fail to develop at all. Now it is evident that in the human, the doses of protein taken in food will as a rule be enormous compared with one one-hundredth-thousandth of one c.c. in a guinea pig, even allowing for the fact that an adult human is likely to weigh as much as two or three hundred guinea pigs. The same thing is true concerning the doses of horse serum, milk, etc., usually given to the human. But above and beyond all these facts, lies the important one that in many respects the human is undoubtedly more stable in many ways than most of the lower animals are, and it is not unreasonable to suppose that he is more stable in respect to sensitization.

Desensitization

So far, *anaphylaxis* appears as a de-adjustment rather than an adjustment. A disease poison such as diphtheria toxin, when admitted into the body produces ill effects at first but also causes reactions of the body to itself, thus gradually immunizing it; or in other words, the body adjusts to the poison. In anaphylaxis, however, the for-

eign protein "sneaks," so to speak, into the body and without any sign of its presence or its activities, prepares the way for later trouble. An invasion by a second portion of the same substance finds conditions favorable to an anaphylactic explosion and at once precipitates it. Thus, if we think of the diphtheria toxin acting by a direct frontal attack in the open, the *sensitizing protein* may well be likened to a spy who enters a foreign country in disguise and though making no uproar himself, "disaffects the natives" and so paves the way for his associates who will come later. Certain it is that this "spy"—the first sensitizing dose—undermines in some way the resisting powers of the body; but it is itself perhaps thereby exhausted and must leave to its associates the task of carrying on the undertaking.

This first sensitizing does encounter many difficulties in its attempt to sensitize the body, just as bacteria also meet many obstacles to the effective poisoning of the body. It has been already stated that if the first dose be large, immunization rather than sensitization may result. This perhaps explains why anaphylaxis remained undiscovered so long, since it was not appreciated until the refinements of modern laboratory investigation diminished the doses of serum used.

Another obstacle to sensitization is that anaphylactic shock does not develop unless there is a lapse of about ten days, roughly speaking, between the first and the second dose. If *within* the ten-day period, other doses of the same protein are administered to the body, and especially if these doses are administered daily after the first, immunization again rather than sensitization is produced. For instance, in the case of the ordinary proteins taken as foods, the repetition of the same proteins meal after meal tends to offset the effect of potential sensitization at any one meal. On the other hand, continuous exposure to a given protein may be the factor which results in sensitiza-

tion; for if the conditions of the intestinal wall which permit the passage of the unaltered protein occur but seldom and intermittently in those persons who show them at all, then any protein frequently used is more likely to encounter one of these rare occasions than would a protein rarely used.

Process of Desensitization. Recognizing these points in the difficulties which beset the development of both initial sensitization and subsequent anaphylactic shock, the avoidance of such shock is now based on tactics similar to those which are used to protect non-immunes in case of infection; *i.e.,* desensitization to proteins has been worked out on a basis quite similar to that of immunization against toxins. This will be recognized as no more than our old "getting-used-to-it" principle, our old method of *adjustment by graduated slow exposure with intervals of rest.* Thus a person obviously sensitive to a certain protein may watch for and evade that protein exactly as a non-immune may watch for and avoid anyone suffering from measles. In a case known to the writer, a nurse was extremely sensitive to raw celery, but since raw celery is easily recognized in a meal, she found it easy to escape attacks from this source. Sometimes as in the case just quoted, the objectionable protein is so changed by cooking that cooked dishes need not be feared. But persons sensitive to eggs or milk or other proteins much used in combination and especially if they are sensitive to these proteins when cooked as well as when raw, might have great difficulty in avoiding the dangerous protein without confining themselves to special and restricted diets.

Thus *evasion* of trouble, simple enough with some proteins, becomes so difficult with others and so often involves real deprivation from the nutritional standpoint that desensitization is sought as a preferable alternative. Such desensitization may be accomplished, as has already

been stated, by administering the guilty protein in very minute doses either by injection or by mouth.

Naturally the first *desensitization dose* should be smaller in amount than that necessary to produce a serious anaphylactic attack; and the subsequent doses should be increased gradually and slowly with definite intervals between doses. By this process the patient's body will in time become able to handle without harm a dose of the guilty protein greater than any he is likely to encounter in ordinary life. It would appear that desensitization of this character resembles that form of immunity known as tolerance, rather than the forms developed in most of the acute cases of infectious diseases. It will be remembered that tolerance as found in such diseases as malaria and syphilis disappears when the demand for it vanishes. So also desensitization once attained may be lost unless the protection involved is reinforced more or less frequently. In the absence of demand, immunity against the offending protein may disappear and the patient may find himself back in his old condition of anaphylaxis.

"Natural" Anaphylaxis

Although anaphylaxis is generally acquired after birth, it may also, like immunity, exist from the moment of birth, possibly being acquired *in utero* from the mother as smallpox may be; but sometimes at least it is truly hereditary. A tendency to various forms of anaphylaxis appears to "run in families," relatives of an asthmatic having perhaps not asthma, but hay fever or frequent attacks of such ailments as hives or eczema.

Although acquired anaphylaxis in the human is practically always an active anaphylaxis, that is, anaphylaxis due to the reaction of the body itself against invading foreign protein, just as a passive immunity against some diseases may be acquired by taking into the body a ready-

made antitoxin from the horse, so at least experimentally a passive anaphylaxis may be developed by taking into the body the serum from a sensitized animal. As in passive immunity, so in passive anaphylaxis, the duration of the acquired passivity is short compared with the duration of a state actively acquired.

Summary

Anaphylaxis is in many respects the converse of immunity. It is a state of the body in which it can be poisoned by a foreign but ordinarily harmless protein. This state of sensitization is acquired only by the introduction of the foreign protein in its protein form, and is specific for the protein thus introduced. In addition to the acquired form, it would appear that there are natural or hereditary forms.

Anaphylaxis, like immunity, may be active or passive. Again, anaphylaxis, like immunity, does not develop at once on the introduction of the foreign substance, but only after the lapse of some time, generally in about ten days.

Anaphylaxis once established may be eliminated by immunizing the body to the foreign protein concerned; and this immunization is achieved by the usual methods of gradual, slow exposure with intervals of rest.

If we attempt to draw an analogy between the poisoning of the body by disease products and that produced by foreign protein, we may consider the former—for instance, the diphtheria toxin—as a poison to which most of us are naturally sensitive and which therefore poisons as soon as it is introduced into the body; while foreign proteins are poisons to which most of us are not naturally sensitive and to which therefore sensitiveness is acquired. The sensitive state may be abolished in either case by immunization, the result of exposure to the offending substance in minute amounts, gradually increased, and taken at intervals.

CHAPTER XIII

THE APPLICATIONS OF HYGIENE

Although the general principles of Hygiene, already discussed, have had their application indicated to some extent in the process of explaining them; and although, if themselves understood, these principles carry with them suggestions at least of their usage, yet certain of the applications are here renewed or elaborated.

The first of these principles, that man and his body are outgrowths of Nature, products of the planetary soil and air, patterned upon Nature's other products, and subject in every feature to Nature's general laws, applies to man's mind as well as brain, to the brain as much as to any other part of man's physical and chemical make-up; to all his activities within his own body as well as without. Hence we may conveniently divide our applications into those concerned with the body and its activities—physical hygiene; and those concerned with a special part of the body, the brain, or rather with the special activity of the latter, thought. This latter application is known as mental hygiene.

Physical Hygiene

It has been abundantly pointed out in preceding chapters that man through his mental activities can control his physical hygiene—that is, can control the reactions of his body to his surroundings—to a very considerable extent; but also that he does not effect this control to any great extent through the direct action of his will power directly

upon those abilities. This is because these abilities, being largely automatic, are, very fortunately, largely free from conscious administration. Hence they react to his surroundings, and to changes in them, without his conscious volition, many times even against his desire. As examples, especially of the reactions that occur despite mental opposition, are blushing when caught in a lie, yawning in a host's face, winking when firing a rifle, ducking to a bullet overhead, perspiring under worry, and many others well known. Conversely, desired reactions may be suppressed by the effect of surroundings, innumerable examples of which are seen in disease.

Man's control of his automatic adjustments is largely indirect, and depends on the control he may exercise on his surroundings, rather than directly on his own internal body operations. Thus, by seeking or avoiding the particular surroundings which call for a certain adjustment, he may elicit or suppress the activity of that adjustment. Thus involuntary shivering from cold may be stopped entirely by wrapping up warmly or going close up to a fire. By regulating the demands of his surroundings he may indirectly regulate, develop, or modify his adjusting abilities.

True, by will power, partial control of reactions, at least of some of them, may be attained; thus, with some effort, a yawn may sometimes be suppressed; accomplished rifle shots may learn not to wink, at least until after the explosion; the old soldier may not duck under fire. Although by will power we all can increase or diminish the depth or rate of respiration, the demands of the body for a depth or rate suitable to the surroundings may reach a point where mere will power loses control. No one is able to hold his breath, even in fear of death as when submerged in water, beyond a certain point. When that point is reached, the automatic mechanisms seize the reins, and an inspiration ensues, even though the lungs be thereby

flooded. But by exposing ourselves voluntarily to the conditions calling for adjustments of the respiratory depth or rate, these adjustments, even to extremes, may be made and continued for long periods. Our volition goes only so far as to select the surroundings. Once the exposure occurs, the will cannot produce—or suppress—the reaction. Thus, one may elect to walk or elect to run; but if one runs, one cannot prevent the increase of the respirations demanded; nor if one then walks, can one maintain the rates used in running. In the presence of the conditions produced by the pneumonia germ in an attack of pneumonia, no will upon earth is strong enough to keep the respiration rate at the usual twenty per minute. The rate rises in accord with the demand, to thirty or forty, without reference to the will; even when the patient is unconscious.

No more important principle—the control and development of automatic adjusting abilities indirectly, through direct control of surroundings—is known to practical hygiene; and no more important application of Hygiene can be made than the choosing of those forms of surroundings that will tend to develop, not suppress, the adjusting abilities of the body to all the Universe, within those limits set by the inherent nature of protoplasm. This is the true "promotion of health."

Real education of the body, like real education of the mind, has as its great object to make one feel at home in the Universe; rather, to be, in fact, at home here. But not one-tenth of the capabilities of the average body for being at home in the Universe are ever developed—most of our quite remarkable physical potentialities are left lying dormant throughout life. This is partly because mental education has been so long thought of as a thing apart from physical education, and has been directed to our surroundings rather than to ourselves as a combination of mind and body; chiefly because the great control of sur-

roundings achieved in modern times has deceived us into the development of those forms of control which tend to make body activity unnecessary; and which therefore tend to the disuse of the body's adjusting abilities. Thus, comfort, "a good time," a pleasant life, all absolutely admirable goals, are sought along lines leading to bodily inertia, to bodily quiescence, cultivated by giving to the body surroundings which call for a minimum of bodily effort—adjusting the surroundings to the body to such an extent that there remains little play for the body's adjusting abilities.

With this reduction in the exposure of the body to those surroundings which would develop its potentialities, there has been an increase in the exposure of the mind to a rapid succession of sense images, too rapidly received for digestion, too superficial to be worth digesting. For example, a crowd of baseball fans, movie fans, even church-going fans, sit still in the audience, receiving impressions of the excellent developments of the adjusting abilities of other people, while they themselves pass their lives away with no attention to their own—to this extent living a second-hand life. The bookworm is an example of this same situation—although he despises his companions of the race-track and movie-house. Even active people may lead a second-hand mental life, as in the case of a surgeon who operated continuously and well, yet knew hardly one fact or procedure through his own mental efforts, but derived almost all his vast knowledge from other men's efforts, through books. To such a degree had this gone, that he seemed not to see the real arteries, muscles, or nerves that he handled, except through a mental mist of descriptions, observations, suggestions, from the army of authors he had read.

Thus it is that the most fundamental and altogether the most useful of the rules of applied physical hygiene is this —cultivate body potentialities; and strictly parallel with

it runs the great rule of applied mental hygiene—cultivate the potentialities of the mind.

Fields of Cultivation of Adjustment

Necessarily, the fields in which cultivation of adjusting abilities can be carried out are as numerous as, and correspond in detail with, our innumerable points of physical contact with the Universe. So numerous are these fields that we are forced to classify them in order to grasp them. One very simple classification is that already used, Nutrition, Protection, Race Maintenance.

Under the head of Nutrition, the chief applications of Hygiene naturally deal with the income and outgo of energy. Concerning income, the first thing to remember in practice is that one should cultivate one's abilities to gain body-energy and to build up one's actual body, from any and all available foods; and not to yield the conduct of this truly basic essential to life to mere appetite, taste, or æsthetics. Concerning outgo, the chief thing is to realize that one cannot spend what one has not got; there is no credit system in nutrition; that after each explosion of energy, rest, *i.e.,* time to re-accumulate energy, must be afforded. As a striking example remember the heart. We think of it casually as the most indefatigable engine in existence. The human heart, for instance, we most of us think of as running day and night for say seventy years, a type of most faithful, unintermittent persistence. But a moment's consideration will show that in that seventy years the heart is resting more than half the time. Its ventricles are contracting, expending energy, during but thirty of those years, dilating, relaxing, accumulating energy for the next beat—resting—during the remaining forty. The auricles rest even longer than this.

Those who neglect to cultivate their potentialities, and those who use them to excess, both fail in Hygiene; because both attempt to ignore, not somebody's fad, but fundamental essentials of all protoplasmic life—which, be it remembered, is the only form of life that we know. The tendency to shorter hours and longer holidays has a very sound hygienic, that is, biological basis. Sufficient rest, following action, is a biological, protoplasmic necessity, a *sine qua non* of existence. But those who look forward to an era of all holidays, no work at all, are not merely economic impossibles, but biological impossibles also. Even with those of more moderate views, the well-deserved holidays too often are expended in a whirl of unwonted physical exercise, physical and mental, combined with worry and mental strain, that neither body nor mind is adjusted to. Holidays should be as seriously considered as work days. Biologically there is no difference in importance. The laws of energy, income and energy expenditure, hold in July and December as well as the rest of the year. Who would propose to rest his plough horse by entering him each week-end in a Derby?

Under Protection, the chief application of Hygiene lies in securing immunity in its broadest sense, not alone to the poisons of disease—technical immunity—but also to all the inanimate as well as animate attackers of protoplasm, gravity, friction, cold, heat, etc. Food itself, be it remembered, is really a foreign body; we require immunity against it as we do against disease. To those diseases against which immunity can be secured by the more or less artificial processes of preventive medicine, not involving the suffering of the disease itself, Hygiene teaches that such immunity should be secured. This is a true insurance against certain specific physical ills, as life insurance is against certain financial ills. One takes out insurance against sickness, burglary, fire, not because one knows that any one of them is sure to come, but as a rea-

sonable precaution, costing little when compared with the cost of the catastrophe, should it come. Just so immunity against disease, secured by modern methods, costs almost nothing, absolutely as well as comparatively, and insures the body physically against suffering and death.

Protection, in those diseases where immunity cannot be had without having the disease in full blossom, must be guarded against through watchfulness, through mental alertness and knowledge; in this it is parallel with protection against accidents in general.

Under Race Maintenance, the chief application of Hygiene (apart from the body functions of actual reproduction) lies in the development of faculties other than those directly concerned in the nutrition and protection of the individual who engages in it. The body of the young infant is occupied wholly in nutrition and protection for that same body. But the moment he begins to "help around the house," he begins the first feeble steps in Race Maintenance. He is still concerned, and will be all through his life, with nutrition and protection for himself; without these he would not have the energy nor would he even survive, to carry out the activities of Race Maintenance. True, in the extreme division of labor that characterizes modern civilization, it is not always easy to see at a glance just how some occupations enter into any one of these classes. The farmer, the butcher, the grocer, all have to do with Nutrition, quite evidently; the soldier, the policeman, the health officer, and the physician with Protection. Parents and nurses of all kinds have obvious if less direct functions in securing Nutrition and Protection or both for the race. Entertainers of every description have a function in providing means of rest, both mental and physical, not by any means to be despised, although, as already pointed out, the rest they provide is often taken as a substitute for, instead of a relaxation from, individual effort. It is true that these occupations of man classed

thus as biologically altruistic because they contribute to the lives of others rather than to the individual exercising them, are not always altruistic in the philanthropist's sense. It is true also that these occupations are concerned indirectly from the economist's standpoint, with the nutrition and the protection of the worker; since he derives his own living and is able to buy his own protection out of the proceeds of this work. Thus it appears that nutrition is truly the foundation stone of all life, protection itself being impossible without nutrition; while race maintenance involves both, as well for the individual as for the race.

Hygiene of Sex, Age, Occupation

SEX

Although the general principles of adjustment heretofore discussed apply to all living protoplasm, and therefore to humans, and although humans vary immensely in detail as to their potentialities for adjustment and also as to the degrees in which their potentialities have been elicited, yet the distinctions in these directions, wide as they are for individuals, form themselves into two main sets, which are characteristic respectively of men and women, the masculine set and the feminine set. These differences exist before birth, and become evident to any observer as soon as the new infant is old enough to show any characteristics at all. Although most of the differences are quantitative, consisting in the possession of the same characteristic by both, but in greater or less development, yet also there appear to be qualitative differences also.

Thus, all protoplasm acts by explosion of accumulated energy, which leaves the protoplasm unable to explode again until a new accumulation of energy has been

achieved. The tendency is for the masculine type of explosion to require a more powerful stimulus than the feminine, to be more powerful when it occurs, to require more rest for re-accumulation of energy; while the limit of length for a series of such explosions following each other is less.

Age

In youth the potentialities are usually the most readily elicited and adjustments most easily and quickly made; of course this does not apply to adjustments necessary for reproduction, since these lie dormant, practically speaking, during the first decade or so of life. But while youth is the time for exposure to the demands of environment with the corresponding development of the adjusting abilities thereto, it is also the period in which the slow-gradual-rest rule preëminently applies. "Little and often, but not too often," is the slogan for this period.

The young child, for instance, is readily *immunized to all sorts of foods,* and they should be presented to him so that he may develop the necessary adjustments; but each of these new foods should be given with particular attention to "small doses" gradually increased at sufficiently long intervals. Parents who do not recognize that each new food is a foreign body which is likely to cause some upset when first used may fail to give the first doses in small amounts and so fail to minimize upsets if they occur; for the same reason, they are liable to regard an upset as an indication of permanent disability for that food, denying it ever after instead of continuing to administer it until immunity develops. This principle applies to all the adjustments of the young child. If each adjustment were interdicted on the first sign of pain, most of the necessary adjustments in life would never be made.

As age increases, the development of new adjustments

proceeds less rapidly perhaps, but as a much larger "dose" may be endured at the outset, the ultimate results are about equal. Ignorance of this fact leads to a most pitiable misapprehension among old people, middle-aged people, and even in young adults who sometimes think that their hitherto undeveloped adjusting abilities can no longer be elicited and that those things which their bodies did not adjust to as children are forever out of their reach. They are even more likely to take this attitude in regard to their mental life than to their physical.

Yet the truth is that even at fifty, adjusting abilities, instead of being lost, are perhaps on the average but one-third slower than in youth; and that this is offset by the larger dose that can be taken each time. The disabilities of age are real enough, but these exaggerated beliefs concerning them act to prevent even the attempt at new adjustments, or the early abandonment of those made, with a consequent result that old age in effect is entered upon before it appears on the scene in reality! Old age may attempt an adjustment, and may succeed; also old age may attempt an adjustment and fail. But middle-age or youth, failing even the attempt, is defeated before the battle. The now common examples of old men learning to play golf or to drive an automobile are excellent illustrations of this. It is even debatable whether the adjusting abilities fail even as fast as above suggested—whether conscious adjustments at least are not slowed rather by lack of concentration than by real lessening of the ability to adjust. If the latter be true, the apparent slowing is really psychic rather than in the physical mechanism itself. To the young child, learning to jump or to say the multiplication table for the first time are great enterprises in a mental field relatively clear of impressions and plans and memories; they loom up immensely in the mind. But the same things to an adult are but items in a whirl of other things, and can catch as a rule but a momentary, abstracted attention.

The child spends long painful years learning Latin or algebra; the adult glances once or twice at the Greek alphabet or a geometrical figure, and because he does not remember that relatively infinitesimal impression, concludes that his ability for language or mathematics has gone with the years of his childhood.

Rapid decline in adjusting abilities as age increases is then not truly due to age as a rule, but rather to a disinclination to attempt adjustments, or so strong a disbelief in their existence that the attempt is not made at all. Often, when the attempt is made, an upset or partial failure no greater than is normal at any age, is interpreted as indicating loss of ability and the attempt is abandoned just as it was about to succeed.

Occupation

Adjustments to occupation are amongst the most intricate and extensive adjustments, both mental and physical, that we make. As elsewhere explained, occupation is in fact Race Maintenance, and involves such highly specialized adjustments in certain directions as to relieve others of making these adjustments at all. Thus the occupations of the farmer, the butcher, the soldier, mean a high degree of special adjustments for them, and a total lack of adjustment amongst other members of their communities on these lines. The rest of us have the potentialities for all of these occupations, and for many others, but they lie dormant in most of us for lack of a demand from the surroundings.

So far as the hygiene of occupation is concerned, exactly the same principles as already here often enunciated hold in every respect. Adjustment by slow gradual exposure with intervals of rest is the foundation here as elsewhere. The principles of Nutrition, of Protection, of the limits of both hold here as elsewhere. What is called Industrial or

Occupational Hygiene is really most of it Sanitation, which is concerned with the control of the surroundings to suit the body of the worker. Important, even essential as these are, they do not concern Hygiene, which has to do with the adjustment of the worker to his surroundings.

Special Sense Organs

The general principles already given apply to touch, taste, and smell, to sight and hearing. The first three of these, it has been said, put us in touch with our surroundings by immediate contact, the others with things at a distance. But all five require the intimate contact of the external thing with us, with special cells on the surface of the body which are so sensitive to, or capable of detecting, or reacting to, the contact with that thing. In the case of touch, it is quite evident that actual contact with a substance is necessary before we are aware of its presence; in the case of taste, we are aware of the food in our mouths by the sense of touch, but also we have a further sensation, which we would not have from a touch-contact with the same food in contact with any part of the body other than the mouth. This is due to contact of the special taste cells of the tongue with certain chemical compounds in the foods. Most things, food or otherwise, give a taste of their own. One must be careful to distinguish the mere feel of foods from their tastes; crisp lettuce and flabby lettuce taste the same, but the feel of the former is much preferred. Many prepared foods, such as breakfast foods, depend on their feel rather than their taste, for popularity; this is particularly true of any food that has no very striking taste of its own. Smell is probably due to chemical compounds diffused in gaseous form through the air, in extremely small amounts. It is customary to quote the famous grain of musk that after pungently scenting its whole vicinity for twenty years, still weighed one grain

The sense of smell in some of the lower animals is so extraordinarily delicate as to suggest some form of divination; yet that it is dependent on the actual contact of particles with the smelling cells of the nose of the recipient is proved by many facts—one known to all wild animals as well as to man is the simple one that even a herd of deer can be smelled only to leeward; *i.e.,* the particles are real substances, capable of being carried mechanically by the air in its motion. In the case of hearing, a distant vibrating object, disturbs the air in regular sequences, and these, transmitted from particle to particle of air, at length reach those particles of air in contact with our ear-drums. It is the movements of these latter particles that our ear-drums appreciate, and these only. A bit of cotton wool in the ear canal will, to the extent that it prevents the free movements of the particles in contact with the drum, prevent our hearing the distant bell or hammering. Sound is not transmitted in a perfect vacuum. One could not hear the explosion of a sun, in space, however close one might be, although one would certainly feel any particles driven off that rained upon one. In the case of sight, quite the same thing is true. We speak of sight as penetrating space to the most distant stars. But of course, our "penetration" does not extend the millionth part of a millimeter beyond the surface of the retina. The light particles shot out by the sun reach our sight cells just as smell particles reach our smelling cells; or vibrations in the ether are transmitted to the ether particles in contact with our sight cells, just as the vibrations of a bell are transmitted to the air particles next our drums. When a cloud hides the sun—by stopping a flow of sight from us to the sun—it does not do so by "obstructing our vision" as we say, but by obstructing the flow of particles—or vibrations, as you choose —from the sun to us.

These contacts of particles from the outside world affect the corresponding sensitive cells, and travel by way

of the corresponding nerves to our brains. If the nerve be cut or otherwise sufficiently put out of business, no such transfer can occur, and we should not be aware that our sensitive cells were undergoing any contact at all. Under normal conditions, we do become aware in our brains of what is going on at the points of contact, and this is known as a sensation. The duty of the sense organ is now accomplished. What the brain interprets the sensation to mean, and what the brain may plan or carry out as the result of its interpretation is no concern of the sense organ or of its nerves. The sensitive cells are merely protoplasm differentiated for the special purpose of reporting by the nerve wires to the central headquarters what they personally learn. It is up to headquarters to "do the worrying."

The Nutrition of the sense organs is merely part of the general nutrition of the body. So far as nutritional foods or nutritional processes are concerned, they are, apart from their special functions, in no wise in need of any particular form of food or care. It is true that it has appeared that one vitamin, water-soluble A, is related to sight; and it has been held that lack of it may produce "night-blindness" in the human, as well as actual disruption of the eyeball, in rats.

Similarly, the Protection of the sense organs is no different in principle from the protection of any other part or the whole of the body against accidents and disease. Their immense importance to the brain as the only informants which can keep the brain aware of its surroundings—those surroundings, proper adjustment to which constitute successful life—has given rise to superstitious notions concerning their excessive "delicacy," but they are quite hard and will stand as much rough usage in their way as any other part of the body, as is shown by eye and ear surgery.

The special hygiene of the sense organs is that of any

other special group of protoplasmic cells—adjustment to their special surroundings without pain or damage. The improvement and extension of their special abilities to adjust are too little considered. We devote much time and energy to the interpreting of the information they send us, too little to developing their abilities to secure information. They have great potentialities, little cultivated by the average person. These can be elicited by the same processes already described for elicting other potentialities—slow, graduated exposure to the demand for adjustment, with intervals of rest. But few persons, except musicians, think seriously of developing hearing; few but the blind of developing touch; few but the analytical chemist or the tea-taster systematically train the sense organs of taste or smell. We most of us use sight as our chief conscious reliance for information concerning the universe, but even sight is not greatly studied as a sense except by artists.

Systematic development of all the senses should be a definite part of education, which too often is thought of as dealing only with interpretation of sensations. Such training of the sense organs would make the information received by the brain more accurate and more extensive; and in thus furnishing us with better mental images of the universe about us, would improve our opportunities to adjust ourselves in Nutrition and in Protection, and in the great functions of Race Maintenance. Too often smell and touch particularly seem to be devoted chiefly to the discovery of discomforts, not useful or pleasurable surroundings; while taste is confined as a function to the converse, the discovery of pleasant sensations from "foods," which often are taken almost wholly on the basis of this sensation, not on the basis of their real values. Stefansson's experiences with food, as given in his "Friendly Arctic," are well worth serious consideration by all students of hygiene, especially in this connection.

"Normality"

Every student of Hygiene will naturally ask—"How shall I know, for practical purposes, that my adjustments are normal? Still more, how shall I know if my adjusting abilities are good beyond the demands of the moment? Are there tests I can make which will tell me if I see, hear, feel, taste, smell, digest, excrete, etc., as I should? Am I breathing properly? Is my heart sound, my blood pressure right, my circulation in good condition?" Moreover, as the army demands certain standards of physical and mental health and efficiency, before enlisting a soldier, so industry is beginning to ask that the workers shall be physically and mentally sound for their jobs, "adjusted to their occupational environments," before engaging them. The questions of what standards of health, of what degree of adjusting abilities shall be demanded, passes out of the academic or theoretical and becomes a most practical matter. Insurance companies have for long years made and changed such standards, for business purposes; but the average citizen is beginning to want to know, for his own personal welfare.

The answer to these questions can be given—but not as readily as might at the first glance appear. Thus, it is easy to test the sight by attempting to read sentences printed in different sizes of type, and grading the eyesight on the size of the smallest type that is easily read. It is easy to test the hearing by holding a watch at various distances and noting at what distance it can first be heard clearly. Surely those who can pass such tests must be normal, those who fail must have something wrong? In a very general way this is true; but the fallacies and the shortcomings of such tests are so numerous that they should be avoided wherever and whenever anything better can be had, notwithstanding that they are far better than nothing.

Thus, print of a certain standard size may nevertheless be either a clear black, with sharp-cut edges on really white paper, and be read in a good light; or it may consist of grayish, broken letters, on faded yellowish paper, and be read in a relatively poor light. The first set of conditions may enable a person with relatively poor eyes to read it although only with considerable effort; while the second set of conditions may prevent someone with really better eyes from reading it at all. The ticking of a loud watch in a very still room obviously constitutes a very different standard from that made by a low-ticking watch in a boiler factory; moreover, some persons who do not hear well in comparative silence, do hear well in a noisy place. Many other illustrations of the difficulties attending "simple" tests for standardization or grading of function might be given; but one need only remember the intricate apparatus, the physical and chemical calculations, necessary to the simplest forms of basal metabolism tests, blood chemistry, or even a modern urinalysis, to recognize that "simple" inexact, uncontrolled tests are apt to be very misleading, and that real estimation of adjustment and of adjusting ability, if worth doing at all, is important enough to do sufficiently well to give results on which one may rely.

It would be easy to put down here the "normal" blood count, the "normal" constitutents and amounts thereof in urine, and countless other such "standards." But these, without the tests by which they are discovered would be useless, and with the tests would make this a laboratory and clinical guide, which is by no means its purpose. A perusal of the textbooks covering these subjects will quickly convince the reader that only the expert physician who has specialized in these subjects—the normal, its ranges, and the detection of slight as well of extreme departures from the normal—could give an examination worth while.

The Medicine of the immediate future holds out no

greater promise of service to the race than the development of such tests, and their general application to everyone, once, twice or more every year. To establish this will require a desire on the part of the public to receive such services, and on the part of the medical profession to give them. The former shows greater signs of this desire than the latter at present. But once established this system will prove of immense benefit to both profession and public, and result in great gains in individual efficiency, great savings in needless morbidity, and a considerable reduction in premature mortality. It will involve much more careful and accurate examination of the persons who present themselves than are now given, or called for, by ordinary sick patients; the compensation should be correspondingly larger; and the saving in total sickness will much more than pay for this.

It must not be supposed, however, that such tests will consist merely in a long set of determinations relating to the blood count, composition of the urine, blood pressure, etc., although all these and many more will be included. Health means physical adjustment to our surroundings of the moment—adjustment without pain or damage. Thus he is in health, so far as his kidneys are concerned, whose kidneys are at the moment able to handle the needs of the moment. If, however, the situation is such that the maximum abilities of a given pair of kidneys is just sufficient to meet the demands of a very ordinary life, health may exist at the moment, and continue while the demands do not increase; but such a person, it is clear, may be put out of business entirely at any moment by even the slightest demand for increase in kidney function. Obviously, for such persons, the *existence* of health may be established but the *continuation* of health is a matter wholly dependent on whether or not the demands increase; and such an increase is almost certain to occur sooner or later in the most ordinary life. The practical thing to determine, therefore, is

not only the status at the moment, but whether this is being met by the maximum capacity or by the middle capacity of the kidney. If the former, the possessor of the kidneys in question has at best a most doubtful future. If the latter, however, reasonable prospects for the continuation of efficient function obviously exist, so far as the kidneys are concerned. The whole body must be tested on the same basis.

But this is not yet the whole story. Proper functioning of the kidneys does not depend on normality of the kidney alone. It may be quite capable of taking its full share in the purification of the blood sent to it by the heart, but if the heart fails to send the blood as it should, the kidney, although sound enough itself, may be unable to function fully. Or again, although the kidney be in poor condition, increased heart action may compensate for its deficiencies, and a normal output be maintained. In this case, continued health may be a question less of the kidneys than of the heart. This is but a commonplace and cursory example of the whole problem of health—indicating that no mere formula for the normal functioning of each organ can be final; and that the correlation of the various functions with each other, the compensations which have been developed, and the probable stability of these all enter into the account—an account only to be cast up by a highly trained physician, especially conversant with these relations and inter-relations.

Another reason why such examinations should be made by a physician is this: most of us at the present time do suffer more or less damaged adjusting abilities. The layman may, it is true, determine, say, by the watch test that he is deaf in one ear. But only the expert can decide whether this deafness is due to a nerve lesion, and therefore incurable—or merely to wax in the ear, and therefore curable in a few moments; or to any one or more of the many other conditions, the correction of which may be

a slow laborious process. The physician can determine not only the deficiency, but also suggest the remedies, and also apply them, or failing this, instruct as to compensatory or even artificial adjustments. The layman should be at least as chary of doctoring himself as he would be of fixing his own watch.

PROJECTS FOR CHAPTERS X TO XIII

1. As a School Nurse, outline a talk you would give to school children about the care of the feet. Procure slides and illustrations.
2. Make a collection of shoes, both hygienic and unhygienic, and demonstrate to the class the good and bad points of each.
3. Collect footprints of a number of men, women, and children. Compare them with normal footprints and formulate conclusions. Outline the advice you would give to one of the persons whose footprint has been taken.
4. How do you explain the fact that some people have idiosyncrasies in regard to certain articles of food, such as strawberries, milk, eggs? Can such idiosyncrasies be overcome? If so, how?
5. Outline the plans that you would follow in making a thorough study of the markets of your city from the standpoints of (a) hygiene and of (b) sanitation. Follow the plan in the investigation of three or four markets and report on the same.
6. Make an investigation of the water supply of your city and report the results to your class. Make recommendations regarding it and give reasons for them.
7. Prepare an exhibit and plan an educational campaign for a small community with a view to lessening the use of adulterated foods.
8. Prepare a simple explanation of the ways in which a person may acquire an active immunity, and give specific examples of such protection.
9. Give a report of Pasteur's work leading to his discovery of a means of preventing "hydrophobia" from developing in persons bitten by "mad" dogs.
10. Discuss the value and the production of diphtheria antitoxin for therapeutic purposes. Procure lantern slides to illustrate your lecture.

11. Make a study of industrial accidents with a view to determining the relation of fatigue to accidents. Prepare a report for the class with conclusions and recommendations. (Bureaus of Labor furnish valuable information on this subject.)

12. Plan a program of rest and recreation for each of the following: engineer, teacher, metal worker, garment maker.

13. Collect data to show how "carriers" endanger public health. Make a report to the class and discuss the matter of prevention.

14. How would you deal with a young man or a young woman under your supervision, who neglects the care of the nails? Outline the directions you would give and your reasons for them.

15. What arguments would you employ to induce a group of people in whom you are interested to adopt the practice of undergoing a thorough physical examination by a competent physician at regular intervals?

16. Determine what methods are used in making special studies reported. Outline a method for making a similar study of a rural section of your community. Test your plan by carrying it out at least to some extent.

17. Give a complete report of the manner in which your state takes care of children with defective vision.

18. Explain the various lighting systems and discuss the relation of illumination to visual efficiency. What recommendations would you make regarding the lighting of your school?

19. Determine whether you are wearing your glasses properly and taking care of them in the right way.

20. Outline a talk that you would give to high school pupils on the care of the eyes.

21. Outline a course in Physical Education with a view to developing body adjustments. Compare your course with some Physical Culture courses in vogue.

22. Outline for a class of fourth-grade pupils, a lesson plan on the hygiene of the ear. Include specific instructions on a method of developing acuteness of hearing.

23. Look up medical or health journals for reports of specific cases of anaphylaxis and make a study of three or four such cases. Prepare for the class a discussion of one case.

24. Subjects for debate:

Should there be some form of municipal control of milk production and distribution?

Should food handlers be required to take physical ex-

aminations at regular intervals with a view to ascertaining their freedom from communicable disease?

Has the city an adequate method of disposing of sewage?

From the viewpoint of Public Health, is the method of handling garbage and rubbish in this city a safe one?

Should city funds be used for an anti-fly campaign?

Should this city have an anti-spitting ordinance?

A case of smallpox breaks out in a school of 500 children. Should vaccination of all the children in that school be made compulsory?

25. Plan an educational campaign that would convince the citizens of your city that medical inspection of school children would be a good investment of city funds.

26. Outline a plan by which your school can contribute to the hygienic welfare of the city.

27. Prepare a code of health rules for a party of summer tourists who plan to camp en route.

28. Make a detailed plan for a community health week, including publicity, exhibits, speakers, and publications for distribution. Estimate the cost and relative value.

29. How can I improve my own life by:

Hygienic measures?

Sanitary measures?

Epidemiological measures?

30. Outline a plan for community activities for a rural center for one year.

31. Make a library collection of pamphlets on Correct Posture. Study the subject carefully and prepare a lesson plan for teaching correct posture to eighth-grade girls.

32. Plan a Health Program for Hospital Day that can be carried out by student nurses. The object of such a program should be to train the students in health work and to instruct the public in principles of health and hygiene.

33. Write an essay on "The Economic Value of Health."

34. Subjects for debate:

Who was the greater man, Pasteur or Napoleon?

Should the state make appropriations for Nurse Training Schools as it does for other educational institutions?

Should the city support a well-baby clinic?

APPENDIX

A SHORT COURSE IN MODERN PUBLIC HEALTH

Preface

The subject of hygiene, as already presented, is but one part of the great subject of public health. The latter has grown in the last decade or two almost beyond the grasp of even professional students of public health itself. Great governmental bodies, great private bodies, all sorts of associations, committees and societies are struggling with its various phases, not as yet with complete success. To give the reader whose interests are in some one or other of the allied subjects, rather than in the subject as a whole, such a compact view of public health as may serve to orientate him better in his own field cannot but be helpful. This is one reason for the insertion of this "Short Course" here.

Again, teachers of hygiene are frequently expected to teach rather more than is technically included under this term. This arises partly from confusion in the use of terms related to public health, but also because the practical administration of hygienic principles bring up in the field inevitable contacts with the allied fields. It is we who classify knowledge, not Nature; in Nature, hygiene and sanitation, preventive medicine and epidemiology, physiology and therapeutics, health, disease, physical welfare, present themselves in every problem, succeed and follow each other, appear and disappear, in various combinations, as dancers whirl and circle on a dancing floor. One may determine to follow only the evolutions of a single dancer, but soon will find that he cannot ignore the evolutions of that dancer's partner, nor of the other dancers either, if he would really grasp, and especially

if he would really teach, what his own "subject of enquiry" is really doing. Hence another reason for this "Short Course"

Finally, that portion of hygiene which consists in doing for others, in Nutrition and Protection, that which the study of these subjects has taught the student to do for himself on these two lines—that portion of hygiene known as Race Maintenance—is the greatest public duty now before every good citizen. To those who may not have the technical vocabulary or the technical preliminaries in chemistry and physics to fully follow even the simple outlines of hygiene already given, the broader issues of public health, leading to Race Maintenance, may easily be absorbed and will prove of value, personal and public. The race needs the technical people; but even more it needs a great body of intelligent, if necessarily non-technical, citizens who understand what the technicalities are for, even if they do not understand the technicalities themselves. Teachers of hygiene may often find those to whom the technical hygiene is too technical, but to whom this short course may furnish all that is needed. Single lectures on hygiene and allied subjects are often asked for nowadays from hygiene teachers; it is not always easy to cut a course in hygiene into lengths suitable for such purposes; this "course" is already so arranged.

I

What Is the New Public Health?

What is the new public health? How does the new public health differ from the old? The new considers *you* from your skin *in*; the old considered you also, but from your skin *out*. In other words, the old concerned itself very largely with the surroundings—the environment—of people. The new concerns itself chiefly with people themselves.

This does not at first sight seem such a tremendous change—but it is, nevertheless; for it has already revolutionized methods, and has already achieved results on such a scale as

to make it evident that we are turned in the right direction now instead of the wrong. If you want to go to the North Pole, but are headed south, merely turning half round is not such a tremendous change—except that now you may reach the North Pole whereas, as you were headed before, you never would!

Why this change from working on the environment to working on the individual? Well, fundamentally, it is part of the great change in our way of looking at things which was introduced by the bitterly fought but finally accepted doctrine of evolution.

We had been in the habit of thinking of mankind as something apart from Nature—an extra, tucked in, late in the game; a sort of after thought—not part of Nature but in some way different from, superior to, not fitted for this world really. Evolution showed that man really is just as much part of Nature as any insect or plant, just as much part of Nature as a horse or an elephant; not an afterthought at all, but a real product, based and rooted in all the universe; not something different, not something extra, not something unfitted for this world; but on the contrary that man is "the heir of all the ages" in a most literal and real physical and mechanical sense, a real natural outgrowth of Nature itself.

The savage looked upon himself, even more earnestly than we used to do, as "something different." To him all Nature was foreign, antagonistic, filled with evil forces (evil spirits, he called them), all with designs on *him*. His life was one long battle, one long series of escapes, from heat and cold, flood and drought, thunder, lightning, animal enemies and often human enemies. He was self-centered to an extreme. All things outside himself he must run from, conquer or destroy; otherwise they would conquer or destroy him. But as man lost this attitude of the terror-stricken child, kicking and screaming, scratching his nurse's face, opposing everything whatever because of fear of being hurt, he gradually found his great nurse, Nature, who was his mother also, would help him, not hurt him, if only he would stop biting her long enough to find out what she wanted.

So, very, very slowly, with many a slip and stumble, and

many a scar to show for early errors, mankind has reached the point where Nature is no longer a thing to fear, no longer a thing to fight, no longer a thing to conquer even, as a rebellious slave; but rather a bountiful mother, to be studied understood, coöperated with—blood of our blood, bone of our bone, literally as well as metaphorically—and harmful to us only when we fail to understand, or venture rashly into foolish feats.

The force behind the lightning, the pain and fear of earlier generations, we do not fight or flee from; we use it kindly, gently, almost without thought, to cook for us, to move our coal and furniture, to tell our troubles to our friends. Fire, the terror of animal and savage, we use for countless purposes—it has become the "harmless, necessary cat" of modern life.

Disease has been longer than any other of Nature's forces misunderstood, fought against blindly, combatted without real study. Scarcely 70 years ago did the first real glimmerings of what disease really is strike into the human mind in any practical way. Scarcely 30 years ago did the first real uses of that new knowledge begin to show themselves in remodeling human life.

"Coöperating with disease" through understanding of it—a new idea indeed—is the idea which has made the new public health as it has made modern medicine. At first sight this idea strikes us as a suggestion would strike our savage forefathers, that they "coöperate" with fire or lightning or with Niagara. On second sight it strikes us as just as sensible as furnace heat, or telephones, or hydro; and so it is.

We now use the forces of disease to cure, and even better, to prevent disease, as we use fire to put out fires with, as we use ice-cold Niagara to warm us.

We do not struggle with the Universe at large to save us from disease, as did our ancestors. We do not fear or dread anything from our skins out. Nothing outside us can hurt us until it gets into us; and often, not even then. Only from our skin *in* can anything harm us; and that is why we have turned from regarding the environment and doctoring it, to regarding ourselves and keeping *ourselves* disease-less.

True, we do forehandedly estimate and prepare in various ways against the causes of disease which exist in our surroundings, but we do not fear, as did our ancestors, these causes of disease so long as they remain *in* our surroundings. They are not to us, as they were to our ancestors, things unknown, intangible, able to strike from a distance like the influences of the stars, or devils. We know to a great extent what the causes of most diseases are, physical, chemical, biological; and that they cannot act upon us except by contact with us. We know also to a great extent how to prevent many of these causes from harming us. Thus we may immunize ourselves against some of them, or obviate their coming to us, or best of all, destroy them altogether.

That is the New Public Health, up-to-date, progressive, aggressive, scientific, public health: and boiled down it means attention to the individual, rather than the surroundings; improving the person rather than the premises; caring for boys rather than for buildings; caring for girls rather than for garbage; caring for men and women rather than for manure and waste.

Therefore we repeat, the New Public Health is chiefly *individual rather than environmental.*

II

Ease and Dis-Ease

Since "coöperating with Nature" and making friends with her forces, with fire, with lightning, even with disease, is *the* wisdom of these latter days then "coöperating with Nature" in securing bodily ease for every one is the problem of the new public health.

The great characteristic of any living thing, the final distinction between a living thing and a dead thing, is the ability which the living thing has to adjust itself to its surroundings. For instance, a dead thing, a stone or a corpse, in the Arctic becomes chilled clear through; in the tropics becomes heated clear through; it is at the mercy of

its surroundings. But a living man shows an unchanged internal temperature, whether he be exposed to Arctic or tropic, summer or winter, so long as he is alive and well, *i.e.*, so long as he can adjust himself to his surroundings. That is what "alive and well" means. Health is "successful adjustment, without pain or damage."

What adjusts our bodies in this remarkable way in every-day life? All we can answer is that living things do it somehow—just how we do not know. The tiniest microscopic water animal, made of only one single cell, if he is alive and well, can and does continuously adjust himself to heat and cold, to water and dryness, to food and starvation (within limits) just as the big many-celled animal does. He does it automatically, as we do, but without knowing how.

It is well for us that these adjustments of our bodies to our surroundings are automatic. For instance, if you run upstairs your heart must pump faster, your lungs must breathe more often, your muscles must burn more fuel. But is it not fortunate that you do not have to figure all this out before you can go upstairs—that you do not have to calculate how fast your heart must pump, your lungs breathe, your muscles burn! Many, many other things besides just these three occur also when you run upstairs, and if you had to figure them all out first, you would never get upstairs at all. Being automatically adjusted, however, your body attends to all these changes without thought on your part—without your being conscious of one-tenth of them. If you are in health, you go upstairs and down all day without even noticing that your body arrangements change.

This automatic adjustment, when it runs smoothly, unconsciously, without pain or damage, is ease; is health. When your body refuses to adjust itself, or if your body adjust itself only with pain or damage—then you have dis-ease.

It is evident then that your surroundings do not matter, because they cannot harm you, provided you are now comfortably adjusted to them and can in the future adjust yourself to any change. The Eskimo is just as happy, comfortable, healthy, in his, to us, terrible snows as the Solomon Islander is in his beautiful tropic—and both because they are adjusted

comfortably, each to his own surroundings. Now exchange the Eskimo and the Solomon Islander suddenly and see what disaster happens! Of course, if you exchange them gradually, giving their bodies time to adjust, both Eskimo and Solomon Islander will come out all right. To be able to adjust yourself to your surroundings is a great thing; but to be able to *change* those adjustments (within limits) as the surroundings change, is ever so much greater.

Ah! that "within limits!" There steps in the difference between gods and men. However carefully you train your heart to climbing stairs, or mountains, there are speeds and slopes which will break it. However slowly you harden your hands to rowing, or digging, there are tasks that will blister them still. However well you adjust yourself to heat and cold, there are heats or colds that will burn or freeze.

Man's great advantage over all other animals is this—not only can he, like them, adjust himself (within limits) to his surroundings; but also he very often can so control his surroundings that he can reduce the demands they make on him for adjustment. For instance, the bear or seal, exposed to bitter Arctic cold, at first adjust themselves to it; but if the cold exceeds their limit of adjustment, they cannot do otherwise than die. Adjust or die—that is the law of the lower animal. But man, when the cold exceeds the limit of his adjustment, lights a fire and so reduces the temperature he has to meet; thus making his surroundings suit him instead of suiting himself to his surroundings.

There at once is the triumph and the pitfall of civilization. Because we find it far easier, as a rule, to adjust our surroundings to ourselves than to adjust ourselves to our surroundings, we grow lazy physically. Our very word "comfort" implies, not our ability to suit ourselves to our surroundings, but our ability to make our surroundings over to suit us. This means, sooner or later, the loss of our ability to adjust ourselves readily to changes in our surroundings; a loss, that is, of the chief feature and virtue of being alive! Man is in health if he is properly adjusted to his present surroundings. If he can prevent his surroundings from changing he will remain in health so long as his present

adjustments act. But in this world changes in surroundings are sure to come. A healthy state is, therefore, not merely a state of present adjustment, but a state in which the adjusting ability is kept up to a high mark in order to meet inevitable changes when and as they come. Health (ease) is not a fixed condition and is not achieved by living under fixed conditions. Constant changes in the surroundings (within reasonable limits) are really necessary in order that our ability to adjust ourselves may be maintained and developed in order that true health may be had.

No greater single truth in public health exists than this one—that health depends on our ability to adjust ourselves to our surroundings. This may be achieved best by (a) cultivating our adjusting abilities to meet the demands made by our surroundings; or may be achieved, less well, but still well enough by (b) controlling our surroundings, so that the demands made by the surroundings on our abilities to adjust are reduced. It is best to cultivate your heart until it can stand easily, without pain or damage, running upstairs or climbing mountains. But you can get along well enough without cultivating your heart, if you keep away from stairs or mountains. The same principles apply in meeting such forces of disease as chemical poisons, or the greatest of the forces of disease, germs. You may (a) adjust yourself to them, making yourself proof against them, or (b) you may evade them, or (c) sometimes you may destroy them. Of this later, however.

Health then, is comfortable adjustment—ease.

Disease is uncomfortable, painful or damaging adjustment —dis-ease.

Death is the result of complete failure to adjust at all.

The new public health is designed to secure efficient adjustments, and so to do away with disease and to reduce premature deaths.

III

What Must We Do to Live?

Nature's answer to that age-old question is very definite, very clear, very emphatic. There are two things every indi-

vidual living thing must do to live. Why you want to live is no concern of Nature; but if you want to live you must look out for (a) nutrition, and (b) protection. If also you want your family to live, your people to live, your race to live, you must look out for race maintenance as well.

The three great blind, driving forces which, willy-nilly, keep and have kept, all down the ages, living things alive upon this earth are these three—the need and the desire for food, the need and the desire for protection from invaders of all kinds, the need and the desire to maintain the race. The higher we ascend from germ to plant, from plant to animal, from animal to man, the more obviously evident the need for these three great things becomes.

See, now, how essential they are, how they belong to the inevitable—thus: animals as distinct from plants take their food by force, killing other living things that they themselves may live. From microscopic amœba to elephant or whale, all animal life feeds on other life, on other animals or plants. Of all living things only plants can live on non-living things, such as soil, water, air. All animals require for food living matter, or matter that has been very recently alive.

Therefore, it is that not only all animals and plants require to get food for themselves (nutrition), but also they require not to become food for others (protection). If we are to live we must eat, but also it is quite clear that if we are to live we must not be eaten! Protection includes defense against mechanical violence—accidents—and chemical poisons also; but these are minor matters comparatively; they represent "attacks" from non-living things.

In early days man himself was constantly between these two predicaments—he must venture forth from his cave to get food, but in going out thus for food to preserve his life he always risked his life. He did not always get home again. He stayed out, sometimes permanently, furnishing in his own person a meal to some wolf or tiger, python or alligator. In these days man must likewise venture forth from his home to get his food, not, it is true by direct hunt, capture and slaughter as in the old days, but indirectly, by earning

the wherewithal to buy his food from those who do directly slaughter beef, poultry, sheep, etc. In so venturing forth he does not now exactly risk making a meal for wolf or tiger but he often picks up certain germs in his daily grind which attack him no less fatally than a wolf, and just as truly eat him as ever wolf or tiger ate his ancestors. Of course, like the cave men, our modern citizen may encounter mechanical violence, taking to-day the form of an automobile "attack" rather than a falling tree or boulder, and he may encounter human enemies such as the hold-up man or other thugs.

Thus it is that the greatest source of our physical ills in this world is this same universal need for nutrition, and nutrition is the greatest source of our ills because the need for it is so universal. Nutrition from the standpoint of supplying nutriment to ourselves is quite all right, from our standpoint, although it keeps us busy doing it. But nutrition from the standpoint of furnishing ourselves as nutriment to germs, who also need nourishment to live, and unhappily want to live on us, is quite the reverse—to us. Ninety per cent of all our "diseases" are due to our luckless situation in constituting the favorite food of certain germs, just as ninety per cent of the troubles of cattle, sheep, swine, poultry, is due to their luckless situation in constituting our favorite food. As tuberculosis, syphilis and other germs are our great plagues, so we are the great plagues of cow and goose, greater plagues than wolf or tiger ever were to them—or to us.

Well, then, so far there is no difficulty in understanding that nutrition and protection are two things that we must achieve to keep alive. But race maintenance is something far harder to understand. Why should the animal, well fed and well protected, desire to maintain not only himself but also his race? What makes the mother (and father, too, sometimes) give up their food to, or risk their lives for some other young life? The wolf and tiger, to us the very symbols of destruction, malignity and meanness, will go the limit to feed and to protect their own descendants. For this maintenance "urge" we have no ready explanation, but we know it exists, and is immensely important, one of the great

facts of life, for nine-tenths of all the activities, sacrifices and aspirations of man relate to such race maintenance in some way or other. True, food is more fundamental, more fundamental even than protection; without food, protection is useless; without food there would be nothing to protect. Any animal will risk his safety to get food. But having food, the next thing is protection—avoidance of the fate of forming food for others. Yet, having food and safety, then comes in race maintenance, to secure which both food and safety, despite their enormous value, are readily surrendered.

Beginning crudely with care for the children this curious "urge" extends itself in some species to the immediate associates, as in herds of deer, or elephants; in man, to his whole town, his province, his country, until in its broadest form "race maintenance" becomes "the brotherhood of man."

Proper adjustment between our bodies and their surroundings is the great art of successful physical life; the reverse is disease. Now we can see that the three great fields in which we must make these adjustments are the fields of nutrition, protection and race maintenance—the first two for ourselves, the third for our own kind. Every activity of man relates in some way to one or two or all three of these.

Now, nutrition means not merely eating food, but includes the whole process of getting food, eating it and burning it up within our bodies. It, therefore, includes food procuration, food transportation, cooking; and it includes breathing, for it is by breathing that we get the oxygen which burns our food; it includes also all those incessant activities (metabolism) within our bodies which convert the heat thus obtained into action, sensation, thought. So also protection means not alone guarding against wolves and tigers and other living things, but often against other humans; and also against non-living things that may destroy us—cold, heat, flood, fire, mechanical violence of all kinds, chemical poisons. Protection against all of these is needed, but all put together the dangers to our lives from all sources other than germs are not one-tenth as worthy of consideration as the dangers from germs themselves. To make this clear, look at this simple fact: During the great war 14,000 Canadians were killed each year

by battle. During the same four years (but also both before and since) 60,000 Canadians were killed each year by germs. Since 1914, then, war has cost us 56,000 lives, but germs have cost us in the same time well over half a million lives.

Whatever we can do to secure proper adjustments for ourselves in the three great fields of nutrition, protection and race maintenance must be done by "coöperating with Nature;" by finding out what Nature requires, and adjusting ourselves to these requirements. Fortunately the adjustments we are called upon to make are made quite readily, indeed most of them automatically, and we cannot as a rule improve upon them very much. On the other hand, we can and often do most terribly misunderstand and muddle them by careless interference! Too often even now we figure out of our own heads what we think Nature ought to want and then in reckless fashion proceed blindly to foist upon Nature *our* opinions. Now, our opinions constitute one thing that Nature does not care about or consider in the very slightest! So it comes that hardly one single teaching which was current 20 years ago in public health but has this fault deeply imbedded in it, for our forefathers did not bother Nature to find out what she asks of us. No; they figured out what things they would ask of Nature—as if they were running things!

Nature asks of us, as of all living things, adjustment of ourselves to our surroundings, and Nature furnishes us (within limits) the wherewithal to do this.

In some matters we, in contrast with other animals, can in many ways adjust our surroundings to ourselves, and this gives us our preëminent place amongst all living things, for most living things have very little control of their surroundings and so live almost entirely at their mercy.

The chief fields in which such adjustments must be made are those relating to nutrition, first and most essential; to protection, the next in order of necessity; and lastly to race maintenance, without which latter the individual may succeed but not the race.

IV

Nutrition Up-to-Date

We are wrong and the Chinaman is right in the way we count up how old we are. When we say a child is one year old, the Chinaman would say, "No—two yeals ole." Certainly; for nearly two years, not one, that child has been alive, which means taking nourishment, growing, moving, throwing out waste products, adjusting to environment, but above all, taking nourishment. We all begin our nourishment-consuming careers at a stage when we are about one-sixth the diameter of that tiny mite which produces scabies more commonly known as the seven-year itch. This itch-mite (really a degenerate spider) is about the size of the dot on the small letter "i" used in this article. You weigh, say 150 pounds at 21 years of age. You have grown all the way up from that tiny "one-sixth of an "i" dot (how much did you weigh then?) to your 21-year-old weight, by *nutrition,* that is, by taking in food.

But you have not used just 150 pounds of food in that 21 years; as a matter of simple calculation you have consumed at least 100 times as much as that to keep going, or about 15,000 pounds in those 21 years.

What has become of that 15,000 pounds of food you swallowed? Some of it, possibly 1,000 pounds of it, has gone to form the real living body of you for a time; then, being worn out, has been replaced by still other new material from your food. The remaining 14,000 pounds you ate never became you, properly speaking, but acted merely as fuel, being burned up to keep you going. The story of food in the human body is, therefore, just exactly the same thing as the story of repairs and fuel in an automobile, with this difference; we use gasoline for auto fuel, rubber and steel for auto repairs. We could not reverse this; we could not use rubber and steel, etc., for auto fuel, nor gasoline for auto repairs. But in the human body we can use all kinds of food—milk, meat, eggs, fish, cereals, sugar, fat—for fuel, although only some of these, viz., milk, meat, eggs, fish, cereals and other

foods which contain protein, can be used for human repairs or growth.

The immense amount of food we pour through our systems—somewhere about 1,000 pounds of food a year for the average active adult man—is our way of appropriating for our own use the heat and energy of the sun, from which all the heat and energy on the surface of our globe comes. You cannot nourish yourself by bathing in the sunlight; no animal can. But plants, green plants at least, if given sunlight, can more than merely nourish themselves—get food for themselves; they can *make* food, not alone for themselves, but for all the animal world as well. Animals eat the food which only the plants (by help of the sun) can make from the crude materials in the air and soil. We eat the plants and the animals that have eaten the plants, too, and in both cases we get our nourishment from the plants, after all. Plants are the only manufacturers of food from the crude materials, carbon dioxid, water, salts. Animals are quite helpless in this respect: they are destructive only; they take the food manufactured by the plant and use it up—part of it (some of the protein) to build their own bodies with, but most of it (the rest of the protein and all of the fat, starch and sugar) to burn as fuel. Plants accumulate energy; animals expend it.

All this we have known in a general way for a long time, however. The studies and experimentation of the last few years have made this general knowledge much more accurate and detailed.

One of the important details recently brought to light is this: we used to think all proteins of the same value, whether they came from meat or from cereal, from fish or from beans; that is, we considered protein as protein whether it were animal or vegetable in origin. Now we know that there are proteins and proteins, and that vegetable protein is far less valuable than animal protein for building purposes in the body, although it is just about as good for fuel purposes. This means that children, who have to grow, that is, to add protein to their bodies, require not only some kind of protein to do this with, but milk, meat, eggs, fish and other animal

proteins, rather than the kinds that come from the vegetable world. The adult whose growing days are over does not need protein of any kind so much as the child does; he requires some protein, truly, but whether this comes from animal or vegetable sources does not greatly matter; he does, however, greatly require the fuel foods—starch, sugar, fats and in considerable amounts.

Again, we have discovered about proteins not only that animal proteins (from meat, eggs, milk, fish, etc.) are better than vegetable proteins for building up bodies, and especially for building up children's bodies, but also that the best of all animal proteins for building up infant's bodies are human proteins. Young babies should eat human proteins only; they should literally be young cannibals, in fact, if they are to be successful in after life. No human baby should be anything else than a cannibal for the first nine months after it is born, at least. That is about the proper average length of time that the baby should have *human* milk, not cow's milk, if it can possibly be avoided, and usually it can. The penalty we pay for using cow's milk instead of human milk for babies is the death of four to five cow-fed babies for every one death of human-fed babies! Is that not penalty enough for making babies forsake cannibalism too soon?

The third big thing we know about food (we have only known it definitely about 12 years) is this—that very refined foods and many carefully preserved foods are apt to lack vitamins—a substance we cannot do without any more than a fisherman can do without hooks. A fisherman may starve on the banks of a stream which is full of fish if he has nothing with which to catch the fish. So no amount of protein, fat, starch, sugar, etc., circulating in your blood stream will nourish you if vitamins are lacking to give the body cells a chance to "catch" and use them. While there are vitamins in many of our foods, leafy vegetables, like lettuce, celery, spinach, etc., are the best, and best when eaten *raw*. So also liver, kidney and sweet breads are good and lemon juice, orange juice and tomatoes.

One of the most modern rules for good nutrition to be

added to all other rules, is, use a little raw food every day, among the best of which are lettuce, cabbage and lemons.

Of our three great businesses of life the first, nutrition, is the most fundamentally important.

It may seem hard to believe that the food traditions of our race can be wrong in any respect, or that comparatively very recent discoveries should be right, for man has been eating things on this globe for 250,000 years successfully enough to survive up to the present time. Man must have found out at least 250,000 years ago how to eat, after some fashion, or he would not have lived then or his descendants since. But remember that after all most of this 250,000 years of experience is pure waste, so far as we are concerned. We can learn next to nothing from it about what or how much we should eat. First, because there are few or no records of any of these things except bones of animals and oyster shells in our old ancestors' caves and well-worn teeth in our old ancestors' skulls. We do know, however, that they had hard lives and that even so far down the line towards us as the ancient Egyptians they died, as a rule, old men before they were 50; died with arteriosclerosis, too, just like us. But we live longer than our ancestors and we do it for some reason, not merely that of our relative freedom from war or accidents. Human life has increased an average of five years since 1909, and the average sickness suffered by the average individual has decreased nearly 25 per cent in that time. Surely these facts show that we have learned some tricks our forefathers, even those of the last generation, did not know. We have, and our greatest "trick" lies in substituting experiment for experience.

Whatever you may think of the old ways being best just remember that the old ways killed 300 to 400 out of every 1,000 of all babies before they were one year old; we only kill 80 or 90 now; that in the old days a man was broken down, decrepit (and usually dead) at 50, while now our men of 50 are looking for new worlds to conquer! Improved nutrition is not the whole story, but it is an important part of it; *improved nutrition based on experiment* instead of experience.

V

Protection Against Disease (a) Cure

Disease, we have seen, is maladjustment; that is, a meeting of the demands of our surroundings, but uncomfortably, and with pain or damage, instead of with comfort or ease.

When we say "doctoring" we mean the arts of medicine, of surgery and of nursing, with all their specialties. These are lumped in medical language under the term therapeutics, which term covers anything done for a sick person with the idea of restoring health, or at least, of relieving pain. Therapeutics consists of one or more of the four following procedures: (a) Increasing the patient's ability to adjust himself; (b) reducing or removing the need to adjust; (c) doing both of these at once, or (d) furnishing an artificial means of adjustment. Relief from pain is best accomplished by one of these, as an incidental effect of the really "curative" procedure. When pain is relieved merely by a narcotic instead of by relieving the condition which caused the pain, the "therapeutics" is of a very slim order indeed, and is called "palliative." Pain is the burglar alarm of the body. To relieve pain by narcotics alone is to shut off the alarm; this, of course, does nothing whatever to stop the burglary; indeed, it only makes the burglar happy, since he can now go on burgling, unnoticed and undisturbed.

Take the simple case of a broken leg. Here the patient has pain and damage indeed, quite evidently from his loss of ability to adjust himself to his ordinary surroundings. His ordinary surroundings demand that he shall use that leg to stand on and for other purposes. If he tries to stand on it or kick with it, or walk, he finds infinite pain in doing so, together with failure to achieve the objects of standing or kicking or walking, according to how badly his leg is broken. But he has some ability to adjust left—for his leg is still on him, still has blood circulating in it, still can feel, nourish itself, grow. Beginning with these, the physician may (a) proceed to increase the adjustments possible until the original level is restored; or (b) he may reduce the de-

mand for adjustment, by arranging that his patient does not attempt to stand, kick or walk; usually the physician provides for (c) both; he sends his patient to bed, puts a splint on and watches to see that the repair process proceeds satisfactorily. But if these measures fail the physician may (d) supply an artificial adjustment in the form of a walking stick, a crutch or a modern artificial leg. The physician might, it is true, relieve the pain, the patient's chief complaint at first, by giving a narcotic or anesthetic, without fixing up the leg at all. This would, of course, be an absurd treatment; yet it is exactly parallel to what many lay people do when they take aspirin for headaches, or other "dope" for other pains and ills. Pain is a burglar alarm; don't merely shut off the alarm; find out first why it is ringing—what particular burglar is at work and what he is stealing.

It is not so easy to understand the principles of treatment of a disease as it is to understand the principles of treatment of a broken leg, but if we take the example of diphtheria, we find the procedures are quite analogous. In diphtheria, the patient heretofore well adjusted to his food, eating, sleeping, working, with ease and comfort, now finds all these things difficult, painful, damaging. His temperature, which usually adjusts itself without a thought from him, now runs riot, perhaps four or five degrees above normal. He is "as weak as a cat," in every way out of touch with and unfitted for his ordinary surroundings. If he were compelled to continue to attempt to adjust himself to his ordinary surroundings, he would almost infallibly die. Again the first thing is to (a) restore his adjusting abilities or (b) to change his surroundings so that they demand just as few adjustments on his part as possible, or (c) both; and then (d) to supply him with artificial adjustments if his own fail. The latter, in diphtheria, happens to be the most important of all.

So, to bed with him first; that cuts down the adjustments he must make; then follows the long process of bolstering up what adjusting abilities he already has (to the diphtheria poison) or can quickly develop, particularly the watchful care of his heart and kidneys to secure their adjustment

to the new conditions imposed by the presence of the poison; but chiefly the administration of "anti-toxin," which furnishes the patient with a ready-made artificial adjustment to the very poisons themselves.

The physician's special virtue lies in knowing or knowing how to find out a lot of things of which no non-physician can possibly know; for instance, what particular adjustment abilities have been injured or reduced (diagnosis) in each disease; what adjustments can be dispensed with; how to modify others until they make the smallest demands consistent with life; and especially what, how and when to supply those artificial adjustments which we have discovered. Only a most intimate knowledge of the human machine, in health as well as in disease, can furnish the requisite knowledge, the requisite skill, and above all, the exquisite judgment required to apply that knowledge and skill in any given case. It is not merely a life study—this human body—but a study of hundreds and thousands of lives. No one man ever could learn it all afresh in his own lifetime. Only by the accumulated work of hundreds and thousands of physicians has the needed knowledge and skill been developed, and the even more important professional judgment that makes such knowledge and skill of practical use. Modern medicine necessarily depends upon most careful, painstaking, detailed examination of the patient in every direction, and its triumps show how well such detailed work gets at the real conditions and therefore at their relief.

Here, in the care of the sick, as in nutrition, mankind has had experience for 250,000 years, but here also again, as in nutrition, most of that experience is useless, lost, gone, for lack of records. Moreover, in this "therapeutics," as in nutrition, experiment has replaced experience. Experience, the guide of our forefathers, was as great a thing in its day as was the tallow candle, compared with darkness or a tree-branch torch. But experiment is as much ahead of experience as a 100-watt nitrogen-filled filament electric lamp is ahead of a tallow candle.

It is experiment that has made modern medicine. Therefore it is that all we really know of true value in medicine

and surgery began with the times when experiment began; and modern surgery and modern medicine are for that reason hardly 70 years old. In that brief period (brief as compared with the untold centuries preceding) modern surgery has developed from a live-butcher trade to a really fine art. For instance, of those operated upon in the few crude ways possible 70 years ago, 90 per cent died, usually of blood poisoning; while of those operated on to-day, 99 per cent at least recover. This is not all, however, for our operations are far more varied, far more delicate, far more exact and far more numerous, relieving a lot of conditions that 70 years ago were quite "incurable."

In medicine, as well as in surgery, the advance has been enormous; for instance, 70 years ago, almost all diphtheria cases died, according to the testimony of those days. To-day five per cent is a high figure, if the cases are seen early, and this record is only an example of similar advances in almost all diseases.

In fact, great as have been the advances of surgery, medicine has really delved deeper into the ultimate facts and has made the most conclusive progress. For instance, we have all known for a very long time that in the case of a broken leg, the surgeon does not cause the broken ends to unite—the queer thing we call life does that. You might treat a fracture in a dead man's leg exquisitely well from the surgical standpoint, rest position, apposition, etc., but, of course, there would be no union. In the case of a broken leg, life unites the broken ends. In the case of some diseases also, *it is life alone that cures* (medicine, like surgery, can often only give the patient the best conditions, of which rest is one of the most important). In many cases, we know, just as we do in the case of the broken leg, how Nature adjusts to the disease or "cures" it. But in some diseases (and the list is steadily growing longer) we know more than that; we can actually apply Nature's adjustment ourselves, if Nature fails to act quickly enough.

This curious power of the body to adjust itself to disease poisons (*vis medicatrix naturae*, the curative power of Nature, our medical forefathers called it) has been recognized for

thousands of years and marvelled at. But we in these days, in some diseases at least, actually know what this "vis" is and can make it ourselves and use it and see it act!

Moreover, we are beginning to understand not only how but why living bodies adjust themselves to disease—why "cures" are possible. This tendency to health, this *vis medicatrix naturae,* this curious ability of the body to adjust itself to causes of disease, pain and damage is, we now see, merely a part of the general ability to adjust themselves to their surroundings which all living things have. When such an adjusting ability becomes permanent or hereditary the whole race has gained—it has "evolved" just so much. The tendency to health, recovery from disease, and evolution are therefore all parts of the same very remarkable outstanding feature of living things that we began with in the first article; they are all parts of "the chief feature and virtue of being alive"; they are all parts of our mysterious ability to adjust ourselves to our surroundings. Disease is therefore no more than early painful, awkward attempts at a new adjustment; it is just such pain and awkwardness as we find in learning a new language. The physician is the expert in the fields which are so difficult to the unaccustomed learner—he is the instructor in the new language. He steers and aids and guides the body through its freshman troubles. Thus medicine is or includes the fundamental science of life, physical adjustment.

VI

Protection From Disease (b) Immunity

Of the three great urges that keep the human race going, we have already considered Nutrition briefly, and also the first item in Protection, which is Cure. At present cure is the most widely employed, and the most widely and immediately needed form of protection against disease. Cure consists in repairing damage done; in readjusting after maladjustment has developed; in permitting, so to speak, war to invade our country, then scrambling hard to meet the

enemy after he has already seized part of our country, already slaughtered, burned, and destroyed life and property. We shall now consider the second item in protection, which is immunity.

Immunity consists not in reparation of damage, but preparation against it; not in readjustment after maladjustment has occurred, but in preadjustment so that maladjustment cannot occur; it is such a peace time provision against future war that enemy invasion becomes impossible. Quite true, there are yet two other methods of dealing with war—we may run away from it entirely and so escape it; or we may (perhaps) abolish war. Both these two methods, as applied to disease, will be considered later; just now let us consider the immunization against disease rather than evasion or abolition of it.

Immunity is, if you like, an armoring of our modern bodies against our modern germ enemies, as ancient knights encased themselves in steel against the slings and arrows of their ancient enemies. To make the metaphor modern, it is like fireproofing the "temple of the body" against the fires of disease, so that it cannot burn; or like putting something in your auto radiator so that it cannot freeze. It is, as a method of prevention, the most conclusive that the body itself can of itself provide, and in principle is the most conclusive of any method that can be provided in any way whatever—except the method of abolishing disease entirely, which latter would make immunity unnecessary.

Alas, however, we can apply this beautiful immunity to prevention of disease in relatively *few* diseases; and while it is a very wonderful thing in these few—enough to make the eyes of Hippocrates and Galen pop out completely if only they could see it—it cannot be applied as yet in those diseases that attack us most fatally at present. Immunity has already converted some of what were formerly our most fatal diseases into at present comparatively harmless ones. Naturally enough the remaining diseases, those which we cannot use immunity to combat, continue as our chief plagues now.

Immunization—the production of immunity, the "fire-

proofing" of the human body against disease—has reached its highest perfection in smallpox, through the process called vaccination. Wherever vaccination has been put conscientiously into practice it has abolished the damage done by smallpox, a disease which was the dread and bane of our ancestors to the year 1900.

Against typhoid fever also we can immunize very well, and the recent demonstration on a huge scale in the great war of the unparalleled freedom of the huge armies on both sides from these two old army diseases, smallpox and typhoid, has left objectors without an argument to stand on. Ancient armies usually lost far more men from these two diseases than from any other cause, or all causes combined. As a recent instance, in the Boer war we lost 7,000 men all told from battle and 14,000 from typhoid alone; this is but one recent sample of the long dismal history of almost all campaigns preceding the great war.

There are some other diseases, tetanus (lockjaw) for one, in which immunization saved untold suffering and death in France and Flanders in the same great war; diphtheria can now be prevented, as well as cured, by immunization; and there are good hopes in some other diseases. But in tuberculosis, one of our three greatest killers; in pneumonia, the second one, and in the infections that lead to heart disease, the third; in influenza, in scarlet fever, in measles and in many others we have as yet chiefly hopes; immunity methods have not been developed as well for these as they have been for smallpox, typhoid fever, tetanus and diphtheria.

We can hope greatly for immunity in many diseases. But after all, the best of immunizing methods are useless unless they are used! Only if you are vaccinated will vaccination protect you—obviously. Only if you are immunized against typhoid will typhoid immunity save you. This seems foolishly self-evident. Yet there are thousands of people who do not know that such immunity can be had; thousands more too lazy or shiftless to take advantage of it; and even some with curious kinks in their heads who object to immunization on conscientious grounds. Presumably there were knights of old who had "conscientious scruples" against

wearing armor in those older days. We hear little of such knights now, however; probably because they died early and their conscientious objection against wearing armor perished with them! There may be people who now think fireproofing a house is irreligious—although you may never have encountered one, except among Dowieites or Doukabours.

Why should protecting the body against disease be any more irreligious than wearing a raincoat against a summer thunderstorm, or providing furnace heat against a winter blizzard? Echo answers "Why!"

As a matter of fact, immunity is Nature's own method —Nature's only method—of preventing disease by adjustments of the body to disease germs. It is merely the application of the ancient rule that if you have had certain diseases once—and recover—you will not have those particular diseases again. Every one, even the conscientious objector, knows that smallpox, once suffered, leaves the recovered person proof against a second attack. He may now wallow in the disease, care for smallpox patients ad. lib., go anywhere in a smallpox outbreak and be safe. He does not have to consider evading smallpox or abolishing it—he need not dread the smallpox fire; he cannot burn! Modern medicine, keen on the scent for prevention as well as cure, has taken this indication of Nature's methods and, tirelessly following the details of her secrets, has found the principle on which Nature works. We know now how to secure the immunity without first suffering the disease—we have analyzed Nature's methods and have separated the boon of immunity from the bane of disease. These boons and banes of Nature are generally mixed in Nature's potions; just as Nature mixes both boon and bane in crude coal tar. Modern chemistry has taken that awful coal tar mixture and separated from it the most brilliant dyes we use for hats and ribbons, some useful drugs, some poisons, and many other things. Just so by careful examination, we have found how to separate out from what, to our ancestors, appeared to be only a dark dreadful mass of disease, certain bright gems of value, of which immunity is the chief one up to date.

How does immunity work? The details make a long and

fascinating story. Briefly, immunity production is a part of the same ability to adjust to our surroundings that has been dwelt on in previous articles. If we are not exposed to a certain condition, if no demand is made for us to meet it, we do not, of course, adjust to that condition, we do not make the attempt to meet that something which is not demanded. The dweller in the tropics does not develop "immunity" to cold; there is no reason for him to do so. The wearers of shoes do not develop the ironclad soles of the barefoot savage—they are not called upon by their surroundings for that particular adjustment. But expose the tropic dweller to cold gradually, slowly, with intervals of rest; or expose the wearer of shoes gradually, slowly, to barefoot life, and both adjust themselves. Just so in disease. You cannot and will not develop immunity to typhoid or diphtheria unless you come to deal with the poisons of typhoid or diphtheria in some form. If you wait to deal with them until a full-fledged attack of typhoid or diphtheria is upon you, you run a great chance that in seeking your immunity this way, you will perish. Therefore, we use the separated-out material which will immunize you, without the great risk of death you run from taking Nature's doses unpurified and undiluted. Immunity is just as much a matter of Nature as carbolic acid or diamond dyes; and guarded, measured, carefully applied, it yields us value, not a hopeless muddle.

Immunity is a great method of protection in those diseases where it can be and is used. It is unfortunately only applicable in some diseases; and these are not our worst now. The wise man uses immunity so far as he may, but sees also its shortcomings and its drawbacks. He therefore, turns his eyes to two other possible methods for his escape from disease in the future—evasion and abolition.

VII

Protection Against Disease (c) Evasion

If immunity may be compared with using armor against disease, then evading or "dodging" disease may be described

as using a shield only. When thus unarmored, one's survival must be achieved by quick and skilful movements, eluding the enemies' thrusts rather than resisting them. The well-armored man needs no shield; he need pay no attention whatever to the blows rained on him, for his armor protects him. He may carry on any business he may have, intent on that alone, ignoring the enemy. But the unarmored man, who must trust to minute observation of the enemy, constant alertness, and skilful movements of his body and of his shield to escape the enemy's spear-thrusts, must have his mind continually on that job. A single moment's inattention may result in damage, perhaps irreparable. Precisely is this true of all the measures we can take, in the absence of immunity, to elude infection when it is about us, *i.e.,* when we are "exposed" to it. Remember that "exposure" to some disease germ or other is an almost daily occurrence with all of us who meet other people in our daily work. Not only physicians and nurses are exposed to infection, but anybody, everybody who meets other people to any extent at all.

This "exposure" is not necessarily due to contact with sick people. One great advance in the last 20 years is the definite knowledge that disease germs (which are quite distinct from germs such as those native to soil and water) flourish almost exclusively in the bodies of people; and another great advance is the definite knowledge that they sometimes flourish in the bodies of people who are quite well. Disease germs are parasitic forms, which have lost their ability to take care of themselves, and live as parasites. We do not find them flourishing outside living bodies because once they leave the comforts of home in the living body they have as small a chance of survival as a body louse has when it is shaken off on the floor—and that is practically none. Lice flourish only on the warm, living body—nowhere else. They die out if the person they are on dies—unless they can get over almost at once to some other person who is alive. Just so with disease germs in general—they are "caught" from other live people (or animals) as lice are, not from the surroundings, not from soil or water (with

a few rare exceptions). So it comes about that if you have no disease germs in your own body, and do not associate with other people or animals that have disease germs in their bodies, you will not and cannot become infected (that is, receive disease germs into your body), except in the few and usually rare diseases above referred to (tetanus or lock-jaw, for instance, anthrax, and a very few others).

Our great "killers" (including the three greatest, tuberculosis, pneumonia and the infections that wind up in heart disease, and also syphilis, gonorrhea, typhoid fever, malaria, scarlet fever, measles, colds and most other such diseases) are "caught," in most instances, by close association with persons or animals who already have these germs in their bodies, and who are shedding them to those who come near them. It is possible—it has been done—to remove from its mother by an operation a young animal just about to be born; and to raise it under entirely germ-free conditions. Such animals, free of all germs, are, of course, free also of disease germs, and therefore cannot develop any germ disease at all. Under ordinary circumstances, however, the new-born child picks up germs of some kind in the very process of birth; and if the attendants, the mother or other associates of the child have disease germs in their bodies and are shedding them, the child picks up these disease germs within a very few minutes, just exactly as it always picks up the harmless ones. If the mother, for instance, has tuberculosis in an infectious form, the child will get some tuberculosis germs into its mouth, and so into its system, almost with the first mother-kiss upon its rosy lips.

Under such circumstances, the cruelly-kind method is to remove the baby the instant it is born, without that first mother-kiss; and such children, born of tuberculosis mothers even in the advanced stages of the disease, grow up just as strong and well as other children. If we could—if we only could!—immunize that child against tuberculosis the moment it was born, it might remain with its mother quite regardless of tuberculosis. But, alas, we cannot thus "armor" the child against tuberculosis, as we may "armor" it against smallpox by vaccination. In tuberculosis our only method

for saving such babies is evasion, dodging the germs, blocking them off from the child, because we cannot armor the child against them. Since immunity, or armoring the body, is not possible in many of our diseases, the knowledge of how to "dodge" or evade the diseases in which such immunity is not available becomes extremely important. If you must trust your unarmored body to the protection of a shield, it is surely wise to learn how to wield that shield to best advantage, how to squirm and twist and so to evade the enemy thrusts—unless we abolish diseases, which would make obsolete both shield and armor.

Every physician, every trained nurse, necessarily uses these "shield" methods for their own protection in dealing with infectious patients, except when physician or nurse are already immune to the disease in question. The methods of "dodging" depend on the fact that the germs in a person's body, whether they be disease germs or not, leave that person's body in the discharges of the body—in the ordinary discharges from the nose, mouth, eyes, bladder, bowel and also in such special discharges, pus, blood, etc., as may be characteristic of the particular disease in question. To evade disease, then, you must evade these discharges, but in ordinary life it is not sufficient to evade the discharges merely of those frankly and evidently ill with some definite disease; you must avoid the discharges of all persons, since many persons are shedding disease germs although not themselves sick at the moment. It is by this avoidance of discharges—and by this method only, unless they are immune—that physicians and nurses guard themselves from infection.

This "avoidance of discharges" means in most instances (a) avoidance of the other fellow's mouth-spray, or "breath" as it is popularly called; (b) the avoidance of the other fellow's hands; and (c) the vigorous disinfection of your own hands, if any touching of the other fellow—of his discharges, or of his immediate clothing, etc.,—unavoidably occurs.

This technique, so simple in a well-conducted hospital, is very difficult to employ in ordinary life. One can hardly wear a mask to church or school or tea; very few people nowadays will refuse handshaking; and those who handshake

cannot as a rule wash their hands at once. Yet it is just in close face-to-face conversations, and by the hands (also by kissing) that most infection is conveyed, except in syphilis and gonorrhea. When we reflect on the enormous price we pay for human sociability, as carried out in the "close contacts" of parties, teas, and in our handshaking proclivities, it is also worth reflection that such sociability need cost us no such price but for the fact of widespread infection amongst those whom we meet.

The losses from disease in money, time, heartbreak, disappointments, in suffering, and in death, have been pointed out over and over as the most unnecessary and most without compensation of the losses of the world. Almost every other loss has some compensation, but the loss from disease is without any shadow of return in any direction whatever, except in those relatively few diseases where immunity results—and that is the best return that can be had from any disease. Even "minor" things like colds, because of their prevalence and frequency, mean damage and loss of time not usually appreciated; for instance, the total loss of time from ordinary colds, because of the enormous number of attacks in an ordinary population, is in the aggregate more than twice the loss of time from tuberculosis, a far severer disease, but, of course, much less prevalent.

Evasion of disease is then more widely applicable than is immunity, and can furnish protection against almost all infections, provided it is skilfully, persistently and uniformly carried out. In every-day life it is practically impossible to so carry it out, however. The most skilful physician or nurse, who may have moved for years amongst the most virulent forms of disease in a hospital, completely protected all that time by the good technique of evasion, often, perhaps generally, become infected at some tea or dance or party they attend—because at these latter the technique of protection essential, natural, and in the hospital entirely a matter of course, is found impracticable, or is overlooked in the excitement. To carry out evasion in ordinary social life would mean a complete revolution in our most cherished ways and means of social intercourse, including intimate

face-to-face conversations and handshaking. Again we are up against the inevitability of infection, so long as infection is to be had. Only abolition of infection can rid the world of disease.

Since, then, disease in its most commonly damaging and fatal form (disease due to germs) comes to us from outside, and usually from other people or from animals already infected with these germs, we may largely escape infection by avoiding such infected persons. But in ordinary life, while we may recognize the infected sick and guard ourselves from them, we cannot recognize those infected persons who are quite well without elaborate technical investigations which are usually quite out of question. Hence, to guard against infection by evasion we must guard against the discharges of our associates continuously. But to do this efficiently means either that we must not have associates or that we must treat them with precautions which our present standards of indicating sociability do not now countenance. Unless we rid ourselves, as a race, of infection we must continue to pay the price of human intercourse, meetings, parties, teas, dances, church, etc., in heavy tolls of sickness and of death. Handshaking alone in Canada costs at least $3,000,000 annually (a most conservative estimate) merely in loss by sickness transmitted by hand clasps.

We cannot abandon social intercourse which alone makes modern life worth while; but the thing to do is—make social intercourse harmless by removing the infection which, if it be present, such intercourse inevitably spreads.

VIII

Protection Against Diseases—(d) Abolition

Since dealing with disease by curing it is expensive and also involves first suffering the disease, in order to have something to cure; since protection by immunity is expensive and useful only in very limited fields as yet; since evasion is really practicable only to experts, and even to them is impracticable in ordinary life; abolishing disease remains our

only really conclusive, really worthwhile goal. Any other method of dealing with disease is mere temporizing. The first, cure, is the outcome of the slave attitude of mind; it involves being beaten first and then humbly patching up the wounds, while waiting for another beating. The second, immunization, represents the defensive attitude; meeting active attacks by armor but being quite quiescent in the intervals. The third, evasion, is the bold but risky method of the alert, skilled, confident individual meeting the enemy unarmed and escaping his onslaughts by superior activity and quickness. But the fourth method, abolition, is the conqueror's method—attacking the enemy on his own ground and *destroying* him. As cure and naked defenselessness correspond, so immunity and armor, evasion and a shield, but abolition calls up the strong right hand and the sharp sword; it is the dominating aggressive attitude suited to man if he is really to regard himself as lord of all creation!

If disease were once thus abolished, that is, if one could not contract tuberculosis because tuberculosis had ceased to exist, if one could not contract scarlet fever, because scarlet fever had become extinct, then cure, immunity, evasion and even abolition itself would no longer be matters to do anything about; they would be museum matters, like the armor of our ancestors; they would be things unnecessary, done with, finished; and we might turn our whole attention to other affairs. Fancy a world from which 90 per cent of all our present sickness had disappeared, in which accidents and old age alone concerned us, and in which the former were far rarer and the latter occurred much later than at present!

A piffling dream, this abolition of disease? No! Look around! Leprosy has disappeared now from ordinary life in Europe; yet 500 to 600 years ago Europe had 19,000 houses of refuge (leprosaria) for the innumerable lepers of that day; and Europe then had not one-tenth the population of to-day. If leprosy to-day were still as prevalent as it was then it would mean in proportion 190,000 leprosaria in Europe now! But now there is not one. Leprosy is in Europe an abolished disease.

Piffle? Look around! Yellow fever was so prevalent in Cuba up to about 1900 that huge burial societies with monthly dues existed just because of it. These societies had enormous memberships, 18,000, 12,000, 30,000 men; they existed all over Cuba and spent their dues for yellow fever burials. In less than 10 short years yellow fever was abolished and these societies had nothing on which to spend their funds! They were converted then into huge sickness benefit societies for other diseases not as yet abolished. This abolition was achieved entirely by human intervention—by studying the cause and then destroying it. Since 1900 typhoid fever, so prevalent in Toronto, London, everywhere in North America, has been reduced by an average of 78 per cent and by 90 per cent in Ontario and Minnesota. Its total abolition is quite definitely in sight. This abolition was accomplished entirely by human intervention—by studying the cause of typhoid fever and then destroying it. Tuberculosis has been reduced 31 per cent in the same time, and lesser but still great strides have been made in other diseases, the total effect of which is shown by the addition of five years to the average human life since 1909 (more than one year added every three years)! Time lost by sickness has been cut down by 25 per cent which means about 50,000 years of active work were saved in 1921 as compared with 1909 in Canada alone. This also was done entirely by human intervention, despite the war, despite the "flu," despite ignorance, inertia, the "resignation" so characteristic of the traditional mind.

It is an axiom that what man has done man can certainly do again—and usually man can do it quicker, better, on a much larger scale, each new time that he does it. Huge as is the enterprise of abolishing disease there are correspondingly huge organizations now to carry it out. The Red Cross, the Victorian Order, the Life Insurance companies, are the best known of those which the public hear of generally. Governmental bodies, more reserved, less advertised, too often cramped for funds, too often subject to ancient conceptions and to obsolete laws, are nevertheless also set on the same path. Medicine and medical research have for a long time

pointed out the way; the technical difficulties in most diseases have been largely worked out; the main difficulty lies now in getting the knowledge we possess applied on a large scale to our whole population. Education of the public so that they will know, understand, coöperate, "carry on," is the immediate need. We have so long considered disease inevitable that it requires some very considerable rousing to shake off the old beliefs and to see that most disease is due to nothing more than the attacks of tiny microscopic enemies, precisely as the losses of old days were due to the attacks of larger ones. We have abolished wolves; we have largely abolished lice; we have practically abolished two or three species of the tiny disease germs. Why, then, not abolish all?

True, those diseases we have practically abolished are, naturally enough, ones that were the easiest to handle—smallpox, leprosy, yellow fever, typhus, typhoid. True, even these exist in some places still, amongst the ignorant and those unwilling to take the necessary steps to abolish them. True, we have still the most difficult diseases to overcome, ones that most people think of as inevitable—like colds, measles and rheumatism. But we can look back and show things actually done of a high order—unquestionable gains which have already made this world one hardly recognizable to our forefathers.

What should you do to help on abolition? First, understand the situation, the terrific damage we suffer even now, due solely to disease; and, second, understand the ability we possess to change that situation by coöperation. Then you will set yourself to act on your own initiative.

Look back at the Great War. Remember how hard at first it was to believe a war existed, then to believe that we were involved in it, then to believe that we should take a part, then that the war would ever end, then that we should win. Yet now already nearly *six* years have passed since the war ended; *six* years since we *won!* Just so we now look forward sceptically to abolishing disease, but in a few years of effort we shall look back instead, look back to victory, for it is far more inconceivable that man should lose in such a

struggle than that the allies should have lost in the Great War.

The cost is too great, although the end is good? But, remember we in Canada spend now and lose $270,000,000 every year on account of the disease we suffer—$45,000,000 of this is for the "pleasure" of having tuberculosis alone flourishing amongst us. If it cost us all of this to get rid of disease it would be an excellent bargain. But disease can be largely abolished by spending only about one-third of what it costs us now to have these diseases, to suffer from them, and to pay good cash for suffering from them, too! Moreover, by continuing disease indefinitely we continue indefinitely also our regular annual bill, $270,000,000. But by abolishing disease we would soon be in a position where it cost us only about $100,000,000—the cost of those diseases and accidents we do not yet know how to overcome; and when we reach that point just our cash savings would in 20 years pay our national debt, war loans, indemnities and all!

War is expensive, but not half as expensive as disease—in cash or lives. But war makes a big impression because war is spectacular and is so thoroughly advertised.

Disease makes little impression because it is so commonplace, so a matter of course. It is the unusual that frightens us—we do not count the actual pros and cons cool-headedly. Six hundred cases of smallpox here in any one year would create a tremendous uproar, and be remembered for a generation; but 600 cases of tuberculosis we have continuously, with ever so much more suffering, death, and cost in dollars as well as human misery, yet even now nothing really adequate is done to meet the situation. If we had 600 cases of measles even, people would comment on, resent it, ask for action, quick and efficient, against it.

Nine hundred cases of whooping cough would make still more uproar, literally as well as metaphorically. Like the hen, whooping cough advertises itself loudly in our ears. But 900 cases of venereal disease, our regular allowance, scarcely stir a ripple in the public mind. Yet, how do syphilis and gonorrhea compare with whooping cough, bad

as the latter is, in damage, loss, insanity, disruption of families, death?

Abolition of disease—and we can abolish 80 to 90 per cent of all the physical ills we suffer, outside of accident and old age—abolition of disease is the next great task of civilization. To abolish disease means also to abolish our greatest cause of poverty—there is no single cause, apart from feeblemindedness, so great in producing poverty as disease. It can be done; only a pacifist attitude of mind induced by centuries of submission to disease as something inevitable permits disease to continue. Now that we have broken the shackles of traditional ignorance, now that we see clearly that we can be free and how to gain our freedom, it is inconceivable that we shall for many years longer bow beneath this needless and, because needless, quite intolerable burden.

IX

Race Maintenance: (a) Heredity

First, let us disclaim any reference to politics, local, provincial, national or otherwise; having done which, let us hope that it may be safe to state that the ability to readjust ourselves to our surroundings, which is the chief feature of all life, corresponds to liberalism; while the maintenance and transmission from generation to generation of that same chief feature of life, and of life itself, corresponds to conservatism. The transmission from generation to generation of life gives to living things their form, their structure and their innate ability to operate. Adjustment to the surroundings is the chief accomplishment of life, the chief thing which form and structure actually do; and in the exercise of such adjustments lies the chief method for maintaining and developing the ability to operate at all. Heredity, therefore, gives us the physical capital, consisting in our bodies and our lives; adjustment gives us our interest on this capital, the returns, good or bad, or none, we may get from our investment of this

physical capital. When we invest our physical capital well we have our returns in health, enjoyment, efficiency, long life. When we invest it ill we get meagre picking in returns, indeed.

Some of us inherit unusually good bodies and brains, but invest them very badly, finding our returns chiefly in maladjustment, in disease, pain, inefficiency. Some of us inherit unusually poor bodies and brains, yet invest them so well that our returns in successful adjustment—that is, in health, well-being, achievements—are the envy of all beholders. Most of us, however, do neither of these; most of us inherit only an average amount of capital in body and brain, invest a little of it well, some more of it badly, but leave most of it completely idle. We keep our physical fortune, as misers do their gold in a stocking under a mattress in the attic. Hoarded thus, it will pass on safely enough to our posterity, but meantime it does us no good whatever.

Quite seriously, not one per cent of us ever realize much more than a small fraction (5 or 10 per cent say) of what we might realize on ourselves in health, well-being and efficiency. Most of us are too timid or too lazy to invest ourselves in physically paying propositions, in physical and mental enterprises of various kinds, in things that would return us interest, not necessarily in cash, but in real "interest"—interest in life. Yet health and efficiency do pay in cash as well as in other things, while ill-health and the inefficiency following it are our greatest causes of loss and poverty, as well as of other kinds of misery.

We, most of us, complain of our financial poverty; and it is quite true that there are really but a small number of us who are skilful investors of our cash. But a smaller number still are skilful investors of our bodies and brains! Rather, the majority of us don't invest our physical capital at all, except as our parents, friends or necessity, often the best friend of all, compel us so to do. Even then we do it grudgingly, without real desire to invest, thus leaving most of the magnificent capital we inherit, without its ever costing us a cent, severely alone, untouched and unproductive.

Whence comes this capital of body and brains and life? We do not know, but none of us can add to it, apparently,

and none of us can permanently subtract from it. It is an "entailed" estate, which we receive, willy nilly, from our immediate parents, who received it from theirs, and so on as far back as you have paper to figure on or patience to do the figuring.

Let us see. You have father and mother; each of them had father and mother; each of them had father and mother, and so on. Therefore, you have had two parents, four grandparents, eight great grandparents, 16 great-great-grandparents, 32, 64 and so on. Thus carried out, a very simple calculation will show that each of us has had more than 33,000,000 ancestors during the last 25 generations alone; and this would take us back only to about King Arthur's court. Now the human race has passed through at least 250 generations, merely in more or less historic times. But this is only a fraction of the truth, for if the human race is 250,000 years old, as we have good reason to believe, then each of us has behind him at least 5,000 generations; and 5,000 generations represent literally countless millions of ancestors in the direct line, disregarding such mere side issues as uncles, aunts or cousins!

How much has each or any ancestor affected the capital of brains and body thus handed down to us? What has been added to or subtracted from it, in all this time? An awfully difficult question, this one; but it seems that the changes, if there have been any, have been very slight indeed. In the last 15,000 years at least the changes have not been great enough to become perceptible to the most acute observation. But on the other hand, if our capital has remained practically unchanged, our use of that capital, our investment of it in activities of all kinds, has most enormously expanded. In the last hundred years this expansion has been very evident indeed; much of it has happened in the lifetime of most of us older adults now alive. High school boys of today know more and do more (or may know and do more) than the greatest Greek philosopher dreamed could be known or done. It is not 2,000 years (say 40-60 generations) since our own immediate ancestors were merely painted savages, living and dying stealthily in some wild, stormy islands off the coast of Gaul. The 40 or 60 generations that have elapsed since then have

brought us from savagery to "modern" civilization. Most of that advance has come in the last 3 generations.

Our capital in brains and body, our capacity for improvement, has not greatly changed, if at all; but the increases in the returns on our capital, by more or less wise investment of our capital, has made us "moderns." One may not see after all very much real improvement between the Druids of old Britain and ourselves; yet we must admit some advantages—automobiles, wireless, high schools, hospitals and so on.

Public health, that is modern public health, studies these great inherited potentialities and finds them incalculable; it aims to develop them in judicious foresighted co-relation with our environment, using the latter, not to restrict, but to enhance the former, to give them play and exercise. It does not contemplate surrounding man with restrictive lists of "rules of health"; no one would ever contemplate caging a bird to get its wings in action! To set free the bird, but also to protect it when it is free, from the yard cat, the boy with the catapult, the hawk, from all attackers of all kinds, from frost or draught or other extreme conditions—that is the aim of modern public health, in parable.

It is true that prevention of diseases looms larger in our eyes, now, than this development of health—just as it is more immediately important to save the bird from the hawk than it is to let it try its wings. But if we prevent disease, health will sprout up pretty much of itself and with very little urging. How to attain this development, this sprouting of our potentialities, is our next subject.

It is clear, then, that it does not matter to the race as such what you, one individual in this long chain of generations, do with your capital. Good or bad, you hand it on to your children, practically as you receive it. On the other hand, the investments that you make matter very much indeed to you and yours; although but temporarily. They are of value to the race also, indirectly, not by adding to or substracting from its capital, but in making more easy and more paying future investments by our descendants of the capital when they receive it from us.

After all, it is fortunate that we cannot change much of this

physical capital, that our "bodily estate" is largely "entailed." Think what it would be if all the diseases and defects of all our million ancestors accumulated in us! What awful objects we would be, mentally, physically, morally! We are quite bad enough as we are now!

On the other hand, it seems unfortunate that the great mathematician cannot transmit anything he has acquired in mathematics to his children—that each new generation cannot set off full-fledged, fully equipped at birth, with the accumulated arts and sciences of their forefathers. But as we do not transmit greatly or lastingly our acquired defects which would be ruinous, so also we cannot transmit our acquired accomplishments—or else by now we would be demi-gods. Since neither acquired defects nor acquired accomplishments are transmissible, we are just men; just men, with huge, uncounted, almost unlimited inherited abilities; but abilities which it is clearly up to each individual of us to cultivate on his own hook for his own good, if he would benefit by them at all.

There are, then, no truly inherited "diseases." We do, it is quite obvious, inherit many different types of bodily form, structure and function, in countless different combinations of varying items; and amongst them occasionally some very curious "anomalies" (unusual forms of "capital," not generally useful) like an extra toe, or noncoagulating blood. But "disease" in the ordinary sense is not hereditary. We acquire afresh most of our diseases from our surroundings, and we do not add our diseases permanently to the capital we transmit to our posterity. Of all the things we do transmit, the greatest, most fundamental, most important thing is not disease, but the great preventive of disease—the ability to adjust. Those families whose capital in this respect is largest have the greatest chance to make really good investments, the greatest chance to get returns in health, enjoyment, efficiency, long life. Those families whose capital in this respect is least have very decidedly the short end of things; they naturally drop out after a few futile generations have waged an unequal struggle, unsuccessfully, amidst continuous disaster. So much we cannot help. But in what we can help we fail, too,

most of us; for most of us have these much-needed adjusting abilities all right, and have them in rich abundance, far beyond all reasonable needs; but we do not even begin to think of using them! We "starve in the midst of abundance," not because we cannot, but because we will not take the good things about us.

Thus, then, heredity gives us living bodies, and with them physical potentialities beyond our dreams; nutrition keeps us going; protection saves us, more or less, from untoward ends. The misfortune is that we mostly rest content with these, partly because we do not know what fortunes we possess, but chiefly because we would have to make some little effort in order to realize returns from those same fortunes. It is well that this neglect damages chiefly us; that it damages very little, perhaps not at all, our race. Why not, though, have some of the good things of life for our own selves? Why merely be temporary handers-down to future generations of these great estates, meantime ourselves dragging out a drab existence in mere hovels on their outskirts?

From the physical and mental standpoint (who is wise enough to say just which of these is which?) cultivating the adjustments we ourselves can make in ourselves to the universe about us is the great art of hygiene. The converse, controlling the universe to suit our needs, is the great art of sanitation. Is it not sad that we, like Bunyan's "man with the muckrake," narrow hygiene to merely brushing hair (those of us who happen to have any!) and boots (sometimes); and narrow sanitation to cleaning up our yards, whitewashing our fences!

X

Race Maintenance (b) Developing Inherited Abilities

Since we inherit our bodies, our life itself, and, above all, our ability to adjust ourselves to our surroundings, these three give us our initial capital. The methods of then investing this capital, of securing essential adjustments successfully, is

the important thing in life. There is no subject man can think on more well worth while than this. But no one, fool or philosopher, saint, sage, or bootlegger, can think on it to advantage unless he sees the mechanism of it; unless he grasps somehow, in some fashion, dimly or clearly, ill or well, how it is done.

Why should we invest our capital? Some of us when born, quite literally refuse to invest even one breath, quietly passing back instead, into the "great silence." We record such in our mortality statistics as still-births. We had 74 of these in London last year, about 5 per cent of our total births. Why did these 74 thus refuse further association with the rest of us? There were, of course, numerous different reasons; but behind all of them was some lack of adjusting ability, due in some instances to some kind of defect in bodily make-up; in others to excessive demands this hard world made; or to both. The exact details are of great interest to technical people, to the physician, the pathologist, the public health expert; because, knowing the details, the number of such instances may be cut down. But for our general purposes just now, the main point is this: those still-born babies lacked the ability to adjust themselves to their new surroundings. They, most of them, managed well enough before they were born; they flourished then, and grew. But at their first appearance in the open, they failed; they could not adjust themselves to the first requirements of that abrupt change in their surroundings which constitutes birth; they did not even breathe.

On the other hand, 95 per cent of the babies born in London last year did adjust themselves to their new surroundings at birth by that first important act of breathing. True about 8 per cent of those that breathed fell down within the year in attempting further required adjustments; but they all got this far, at least. Why? Why did you yourself, for instance, make these initial adjustments when you were born? Why did you breathe and eat and grow and develop, to the point where you could read this?

Well, of course, living things inherit the abilities to do these things; but why do they exercise those abilities? It is because they inherit a "desire" to do them, an "urge," a driv-

ing force of some kind, which is part of life itself. The fundamental first of these imperative "urges" is towards nutrition; the next towards protection; the last, most complicated, difficult, expansive one, towards race maintenance.

For instance, successful adjustment to the surrounding air is demanded by every living cell in the new-born infant's body; every cell clamors for oxygen, urges its prompt inhalation, drags, so to speak, on the so far unstirred "wheels" which operate the mechanism of breathing until the machine starts off; or doesn't! The latter situation gives us our still-births, many of them; for then the machine is stalled; the wheels won't turn. But when they do turn, the little new man or woman sets off upon its adjusting life career, begins its first investment in the open of its inherited capital of body, life, and the ability to adjust.

Breathing means burning up fuel in the body; this fuel must be replaced; and so arises the "desire," the "urge," the driving force which calls for food. The mechanism for sucking, swallowing, digesting, absorbing, all the mechanisms for getting food to the cells, are inherited in form and structure, awaiting anxiously the chance to operate. The demands of the body cells set these mechanisms going at the first opportunity, make them try to adjust to the first food which presents itself. But there is yet no adjustment of the body, exterior to the mouth, for securing that necessary food. Food at this stage must be placed actually between the lips, to set the mechanisms working. Later on, adjustment piled on adjustment will enable the infant as it grows to seek its food more and more widely. So at last we have the developed food-hunter, the actual trailer of game through the forest, the skilful fisherman, the accomplished farmer; or the man skilled in various occupations which indirectly achieve the same great end of food, by barter of service or goods with the literal food-getters.

Meantime the infant encounters, in his struggle towards securing food for himself, numerous other and older living things on the same hunt; and some of these hunt him. He finds he must then, to preserve his own body and life intact if possible, escape them somehow, by fighting them off after

he is attacked (cure); by getting himself too tough to be eaten (immunity); by running or dodging too skilfully to be caught (evasion), or by destroying his fellow food-hunters before they reach him (abolition). Thus he is introduced to the second great "desire," or "urge," or driving force which develops his inherited abilities to adjust—the need for escape from enemies, the "urge" of protection. So also still other circumstances, sooner or later, develop the third great driving force, which we call the "urge" of race maintenance, that "urge" which elicits directly or indirectly our greatest abilities for adjustment, adjustments to a vast variety of intricate surroundings—adjustments not needed, not called for, not interesting even, were nutrition and protection alone our goals.

We have, then, these abilities to adjust to our surroundings. But how elicit and develop them voluntarily? How increase our stock of successful adjustments to meet more and more widely all the possible combinations of our surroundings, so that we may more fully "live"—so that we may more completely enjoy life itself, live longer, get the best of what is to be had?

If we examine all the methods, voluntary and involuntary, by which such abilities are developed we will find that some "urge" lies at the bottom of each one, something which drives us on—some demand for something. These demands also are inherited, part of our life itself. Some part of the whole of us clamors for satisfaction, clamors for adjustment. But clamoring alone is not sufficient. Adjustment cannot be made, the mechanisms for adjustment cannot operate unless the surroundings are such that they supply the thing to which you are to adjust. You cannot breathe, however much your body may demand it, if there be no air; you cannot eat, however hungry, if there be no food available. You cannot develop muscular power without using your muscles; there must be work to do before you can work. You cannot develop your thinking power unless there be something to think about. But granted the air to breathe, the food to be had somehow, the chance to move, something, anything at all, to think about, at once the opportunity to develop those mechanisms which

produce breathing, eating, motion, thought, is supplied, and anyone may go on from that point to any further development they wish, in reason.

Thus, the first item in developing such abilities is a demand, an interest, an "urge," a desire to adjust, and the next is the material to which to adjust.

One can adjust oneself to anything pretty much, from eating olives to discovering the North Pole, from dancing to securing a Ph.D. degree, from knitting socks to oratory, if one has the interest, the "urge," and then the actual material to work upon. You may desire most greatly to discover the North Pole, but you will not achieve your end merely by eating olives; you cannot earn a Ph.D. by dancing, or become an orator by knitting socks! So also in the purely physical world you cannot develop your heart for mountain climbing, for going upstairs, or for dancing by sitting still and wishing it were already sufficiently developed; you cannot harden your feet to running barefoot by bathing them in cold cream.

The first rule for developing an ability is to want to develop it; the second is to exercise that ability on the particular thing you want to do, not on something like it, not on a side issue; and then to exercise it on that particular thing slowly, with gradually increasing strenuosity, and, above all, with intervals of rest. We will show later how these principles apply to nutrition, protection, race maintenance, to everything you do or want to do or can do in this world.

XI

Race Maintenance (c) Hygiene

Whatever meanings you may attribute to the term Hygiene, they all boil down to this—the successful adjustments you can make of your body, or of its operation, to the demands of your surroundings.

For illustration, let us consider how we make adjustment to temperature—almost the most important of all the adjustments we can make. Consider, for instance, shivering. If you

are cold, and for any reason cannot move about so as to increase your own internal fires by the muscular effort involved in such moving, you can shiver instead; that is, you can move your muscles amongst themselves, not to go anywhere or do anything, but just to move them. Shivering as we do it usually is involuntary—the last resort of a chilled body. But if you shiver purposely and persistently you will warm yourself sufficiently to prevent the chill. Dogs do this frequently when chained up or when they are just too lazy to run around. You may see them twitching their well-developed skin muscles quite continuously as they sit in a cold wind. We humans have largely lost the art of shivering to get warm or just don't think to use it; but with a little effort we can make the big muscles of the arms and legs and trunk pull against each other and so secure for ourselves the warming effect of exercise, without changing position, and without the chilling which running rapidly through cold air would involve. But why either run or shiver to get warm? Why not make a fire; or put on more clothes? Certainly, either fire or clothes will "warm" you; the first by adding new heat so that your internal fires need not burn so fiercely, the other by reducing the loss of heat from your internal fires and so in time accomplishing the same end.

But building external fires or putting on clothes are sanitation, not hygiene. They are methods of altering your surroundings so that your body need not stir itself up to meet the demands of the surroundings. They avoid and make unnecessary temperature adjustments by your body. Sanitation is therefore passive, hygiene is active. Sanitation makes it unnecessary to cultivate the body by doing away with the enemy, in this case cold. Hygiene cultivates the body to meet the enemy.

Evidently hygiene is almost the only resource of the lower animals, especially of the wild animals; and this is the great reason they "can stand so much"—they have to! Man's control of his surroundings has made it unnecessary for him to keep his adjusting abilities up to so high a mark as wild animals must in this particular of meeting cold, at least.

It is important to remember that we can stand a great

many more degrees of cold than we can of heat. Given clothes enough to prevent too rapid a loss of the heat we make within ourselves, even 40 degrees Fahrenheit below zero is not too bad to be met by the body trained to meet it. This is 100 degrees below the 60 degrees (or 70 degrees) Fahrenheit that we usually consider about right for humans. But now consider what happens if we increase the temperature 100 degrees instead of diminishing it! Who would be left alive at 160 degrees of Fahrenheit? Everybody knows that if we have a 40 degree rise from the usual 60 degrees, at once deaths occur from heat prostration; the number of such deaths from heat in every summer being far more than the number of deaths from cold in any winter.

One of our great problems in hygiene, then, is to keep our body-engines cool enough, and yet not too cool; just the same problem we encounter in running an automobile; but our problem is less to keep our body-engines warm enough, than it is to keep them cool enough.

Why can we stand more cold than heat? Again we turn to the automobile for illustration. See how nicely an auto runs in cold weather, even below zero. (It does not, it is true, *stand still* nicely, in the cold—but it does *run* well!) In the tropics, however, automobiles are not very successful. Again this is a matter of getting rid of surplus heat. Neither man nor auto can operate without producing heat. The auto can rest without producing heat but a man at rest keeps on producing about two-thirds as much heat as he does when he is actively at work. Therefore the getting-rid-of-heat problem is presented to the auto only when it is running; but it is presented to a man all the time, night or day; although of course it is more acute when he is doing something than when he is doing nothing. Hence, you must produce heat—or die; but also you must get rid of the heat you produce—or die.

What we generally call "ventilation"—securing a favorable atmosphere about us—is not really a problem of getting good air to breathe usually, but of getting air which will successfully cool us. Not so many years ago ventilation was wholly misunderstood; it was supposed to be devoted to supplying pure air for breathing. Since 1906, an immense amount of

experimental work has been done in analysing the factors of pure air and of heat loss. We now are quite clear on the point that under all ordinary circumstances of life, the air supplied to the man (or to the auto) for burning up food (or gasoline) need not greatly concern us. It is the air supplied to cool off the engines of the man (and of the auto) that is really more important.

Why are we more sensitive to the heat about us than to the cold? Because we must get rid of our own internal heat continuously and to do this, must be in contact constantly with things (air, water, etc.,) cooler than ourselves. Then they will take away that heat or "cool off." Of course things very much cooler than ourselves may take this heat too fast and chill or freeze us. But our abilities to make internal heat more rapidly when we require to meet the demands of external cold are greater than our abilities to make heat less rapidly when we require to meet the demands of external heat. In other words we can readily stoke up our human furnaces to a high point without damage; but when we try to run them at a low point we are continually shaving the danger zone, because we are running the risk that the fire, if reduced very low, may go out entirely. In this our bodies are uncommonly like the ordinary household furnaces, are they not?

Could not our engines be set to run at much higher or much lower temperatures than they run at now? Possibly; we know some living things, certain bacteria, for instance, that flourish and grow best at the freezing point—others that require a temperature of 140 degrees to 160 degrees Fahrenheit, to make them feel really comfortable! But we humans are set at about 98.6 degrees Fahrenheit for internal temperature and therefore require an external temperature of approximately 60 degrees to 70 degrees to keep us cool enough to run. When the external temperature rises much above this, as in summer, we risk not losing our heat fast enough. It is easy to see that at an external temperature of 98.6 degrees Fahrenheit we would not lose any heat at all and would promptly die from our own internal heat accumulating but for one thing, our ability to sweat. The evaporation of this sweat cools us so well that so long as we sweat, and the sweat

evaporates, we can stand outside temperatures away above 98.6 degrees Fahrenheit.

But in order to sweat freely without damage we must have plenty of water (again just like an auto) ; and we must be able also to evaporate that sweat. It is not enough to have sweat form, exude and stream down our faces and bodies. In order to cool us, it must form, exude and then evaporate, disappear into the air.

Now, if the air is humid, that is, already full of moisture, all the sweating in the world will do us no good, for our sweat will not evaporate into air that is already full of moisture. If the sweat does not evaporate, it does not cool us—and we die.

Thus hygiene, the cultivation of our bodies to meet surrounding conditions, is always limited by extremes in those surroundings—extremes which are beyond our ability to meet. We can adjust ourselves by gradual, slow practice, with intervals of rest, to wide variations, but there are limits. Still within the limits that the practiced body can attain, there are narrower limits, bounding the possibilities of life for the unpracticed body. It is the part of hygiene to develop the range of our adjustments, to widen the distance between the limits —"that we may have life and have it more abundantly" in the physical sense.

XII

Race Maintenance (d) Sanitation

We have seen that public health is an all-embracing business which may be summed up in the phrase, "the science and art of human physical life." We have seen that its chief end is to secure satisfactory adjustments between the individual and his surroundings. We have seen that the chief directions in which these adjustments must be made can be grouped under *nutrition,* which keeps the individual body going by internal forces ; *protection,* which prevents the individual body from being stopped by external forces, and *race maintenance,* which does both these things, but for the race rather than for

the individual. In each direction two forms of adjustment may be made. The first is the adjustment of the body to its surroundings. This is largely done by the involuntary, inherited, automatic capabilities of the body to begin with; partly through voluntary cultivation of those inherited, automatic, capabilities, by the individual afterwards. We call this *hygiene.* The second is the proper adjustment of the surroundings of the body. This is largely an intellectual pursuit. Especially does intelligence come in when decided what is truly "proper" and what is not; what is truly to the real advantage of the body, and what is merely pleasant and enjoyable; but all control of surroundings requires some thought and some effort of a voluntary character. We call this *sanitation.*

Hygiene in its true sense as above defined is, amongst the lower forms of life, dependent on involuntary automatic capabilities almost entirely; the deliberate, intentional voluntary cultivation of these automatic capabilities is chiefly found amongst the most intelligent and progressive peoples. Naturally hygiene has not reached very far yet; we know comparatively little about it. It is almost a new subject, still to be exploded and developed.

Sanitation, the art of controlling our surroundings, has developed far more than hygiene because it is simpler, more concrete, more obvious; because it tends to ease and comfort, to reduce effort; because it does not involve as strenuous bodily effort or bodily discipline as hygiene does, but rather tends to make such effort and discipline unnecessary. Too often inaction, effortlessness, secured by control of surroundings, become in our minds the much-sought-for ideals of life—we look upon mere ease, mere comfort as the equivalent, or rather as much superior to high health and vigor, ability, efficiency.

In nutritional fields, for instance, our food has been refined to please our sense and palates, to make it "easy to look at," to handle, and to chew, until its value to the development of the body has been seriously reduced—in some instances even to the danger line. Thus the very fine white flour which is such a favorite with the unthinking has had certain of the most important parts of the grain removed so that we lose

much of its real value—merely to make it attractive! All the firm parts requiring effort to masticate or to pass onward have been taken out and the remainder chemically bleached. Thus we avoid roughness in our mouths, but our teeth decay; we avoid roughness in our intestines, but constipation results; we please our eyes with the bleached whiteness to the detriment of our body cells, which unfortunately have not yet learned to place æsthetics above worth. In a thousand ways sanitation, the control of our surroundings, has been developed in the purely "human nature" direction, not to secure what is good for us, but merely what custom or tradition tell us we should consider "nice."

Indeed, much of what is called sanitation and devoutly believed in as valuable to health, is sanitation only in the sense that it is a form of control of our surroundings, not in the sense that it is a form of beneficial control; sometimes it is truly detrimental or at best useless to health.

Naturally enough our control of our surroundings has become most complete in the easiest directions—on the mechanical and physical sides of life, in the building of houses, pavements, roads, the making of clothing, the development of mechanical appliances of all kinds to ease our work or our transportation. Then chemistry in the last 100 years or so has given us new controls in other directions, physics in still others; while biological investigation has done a great deal, chiefly, so far, however, for our domestic animals. It promises now to do almost as much for ourselves, sometimes, when we get around to using our biological knowledge to our own personal advantage, rather than merely for our cattle and plants.

We have sometimes mistaken *æsthetics or what we fancy we like* for *sanitation, which is what we need;* while of course, *we are always more or less restricted by economics or what we can get.* We often have to choose for financial reasons between æsthetics and sanitation, sometimes between æsthetics and hygiene. When we have to make such a choice, our chief and very human fault is embalmed in the saying "Give me the luxuries of life and I will go without the necessities!" This is nowhere more strikingly illustrated in more extreme form than amongst those who drink to excess at the sacrifice of

everything they possess that is worth having—family, friends, business, health, life itself. But we all tend to do the same sort of thing, although not necessarily with alcohol or to the same extreme, for we tend to drive very poor bargains with Nature—to spend our money both literally and metaphorically, for the things which are most attractive on the surface, rather than those which are really the most paying ultimately.

Notable changes in our understanding of what is really important in sanitation has developed in recent years. We used to think, and our forefathers were quite sure, that control of the surroundings from the "preservation of health" standpoint meant chiefly mechanical control of physical surroundings, the soil, the air, the materials used in building and in clothing, etc.

Our great recent advance is in recognizing that the "preservation of health" does not depend half as much on precisely what our surroundings are as upon the cultivation of our bodies robustly to meet any or all surroundings within reasonable limits; that is, on hygiene.

Again, we ourselves thought not long ago, and our forefathers very definitely held, that the "prevention of disease" lay chiefly in the same mechanical control of physical surroundings.

We see much more clearly now that the most important of our diseases do not come from the physical surroundings, but from our biological surroundings; not from the kind of air we breathe, or clothes we wear, or houses we live in—that is from the kind of non-living things we associate with—but rather from the kind of *living* things we associate with. This is true whether we associate with living men or animals or insects or bacteria—it is the kind of living men or animals or insects or bacteria with which we associate that governs our diseases much more than the kind of non-living air or clothes or houses.

The old style sanitation naturally dealt with all sorts of minute details concerning inanimate surroundings, to prevent disease; but modern sanitation regards such matters as relatively unimportant and searches rather for enemies amongst our animate associates. True enough, inanimate

things may cause us much distress. Thus inanimate surroundings may produce physical difficulties mechanically, as, for instance, if a tree fall on you or a shoe pinch too tightly, or a loose brick trip you. Chemically also, for one may at times inhale poisonous gases or eat poisonous food, or burn one's skin with acids. But all the physical and chemical injuries suffered by man put together do not approximate one-tenth of the suffering and damage and death resulting from our biological enemies. Cold and heat, starvation and overeating, accidents of any kind, all put together do not do as much damage to the race in any year as just one of our "biological associates," the tubercle bacillus, does in every year.

Therefore, sanitation of the best type to-day is almost wholly concerned with clearing our environment of "undesirable citizens," metaphorically, in the form of disease producing germs; literally, in the form of persons, who being already infected with these germs, spread them to others. It is for this obvious reason that clean-up campaigns and chasing smells—the chief activities of the old-time health officer—have given place to *the study and suppression of infection.* This is sanitation still, because it deals with the control of our surroundings, but this is biological sanitation, not mechanical sanitation.

In this pursuit, public health is merely taking its part in the great war of man and his allies against insects, rusts, smuts, bacteria, protozoa, "germs" in general, which the experts in agriculture tell us threaten not merely disease and death to certain numbers of us, but the very existence of the human race. It must not be supposed that man alone is subject to attacks of such invaders. Our corn, our wheat, our domestic animals, even our lettuce, to say nothing of our shade trees and flowers, are ceaselessly attacked and killed by parasites ranging in size from the locust to quite invisible germs similar to those which cause our own diseases. This invasion of all our larger animals and plants by small ones seems to be increasing; possibly because the territory which supplied wild growing food to such insects, etc., in early days has been taken up by man, with his special plantings and breedings. The insects, etc., now have to eat man's food be-

cause man has cut down and destroyed theirs, and replaced it with his own. But whether this be the true reason or not, the chief struggle of the farmer to-day is against biological invaders, and he finds them much more serious and difficult problems than physical troubles, like drought, or flood or frost or heat. It is, therefore, quite evident that the immense importance of germ diseases in strictly human circles is only one particular phase of the far greater problem of man versus other living species.

Sanitation, the control of our surroundings, includes many items, but the outstanding item is the control of our biological surroundings rather than merely of our physical surroundings.

Therefore public health today is war, not peace; war, not a fad, a philosophy, or "a kind of religion"; straight ruthless war—war of man against other living things. All the objectives that public health efforts in its various departments seek or may appear to seek in any other direction are in reality only side issues and subsidiaries of this main business —war with man's small, smaller, smallest, biological attackers; *man versus the germ.*

Summary

Public health—the all-embracing science and art of conscious physical adjustments between man and his surroundings; including the individual, the community and the race, as it does—what has public health to set forth as its concrete, definite objectives? What simple principles of action can be laid down to guide the inquiring citizen, interested to cooperate, with public health, but necessarily ignorant of its many technicalities?

The final public health objective is to secure for all mankind true "physical welfare"—which means the most nearly perfect adjustment of the best of attainable bodies to the most suitable of physical surroundings. But that pinnacle of achievement is very much above us now. We are as yet only in the foothills about the base of that high, far-off peak.

To reach "Physical Welfare" we must control and direct both of the two factors that enter into it—ourselves, and our surroundings. We must, through hygiene, preserving and increasing our abilities to adjust, fit ourselves better to our surroundings; and we must, through sanitation, restricting extreme conditions in our surroundings, fit our surroundings better to ourselves. But how shall we get at these two, or do either of them well?

Certain of our surroundings, like the earth itself, and certain of the surrounding forces of Nature, like the earth's gravitation, the sun's heat, cold, climate, the atmosphere, we cannot control; we can at best only meet boldly by our own efforts, or else evade, offset, escape the too-injurious extremes they may impose on us. But certain forces of Nature, the biological forces, represented by damage-producing animals and plants, we can actually destroy, removing thus completely from our earth the danger they now threaten. It follows, then, that public health presents two great correlative but contrasting fields—that of promoting health, by cultivating the body to meet its surroundings, and that of preventing disease, by clearing the surroundings of our enemies.

The first cultivates our abilities to meet any and all conditions (within limits) that we cannot avoid; and, by increasing our range of abilities to meet them, increasing also our ease, efficiency, happiness and our chances of long life; the second concerns itself with limiting extreme conditions in our unavoidable surroundings to such ranges as we can easily meet; and with removing from our surroundings, so far as we may, those things we cannot or need not meet at all.

The fundamental guiding principle of all public health enterprises is that its work is prevention, not cure. It does not aim at better or earlier treatment of the sick, but at not having any sick to treat. Public health aims at life saving—as truly as do the great sister professions of medicine, surgery and nursing. But its methods are wholly different from those of the latter professions. Thus, as on every railroad a wrecking crew and doctors' train exist to save life after an accident has happened, so medicine, surgery and nursing exist in ordinary life to care for those already victims of disease. But

public health is represented in this parable not by the wrecking outfit, but by the railroad engineer and the track walker. These latter preventive services aim at saving human life, as truly as does the wrecking service; and on even a larger scale; but their work comes *before,* not after the accident—their success does not lie in prompt, skilful handling of the injured, but in not having any injured to be handled. Public health is like the railroad civil engineer and his allies; not life savers by prompt repair of trouble, but life savers by seeing that no trouble comes.

The preventive measures that can be and are taken by public health concern all known causes of disease, including mechanical causes, like those that produce broken bones: physical, such as extremes of heat and cold, sunstroke or frost-bite; chemical, like those of lead poisoning, alcoholism, drug addiction; nutritional, such as result in rickets, scurvy, pellagra, diabetes, perhaps, and others; but chiefly, overwhelmingly, the struggle with disease is concerned with biological invaders. Therefore public health is war, and not a gentlemannered, sportsmanlike war, governed by rules of humanity towards the defeated, by kindness to prisoners, respect of neutrals. The enemy—insect, smut, rust, bacterium, protozoan—is blind, brainless, implacable, without knowledge, and, therefore, without fear or conscience. In wars of human against human the moral forces are to the physical as three to one on both sides. So every great general has said, so all warriors know. But in this war the enemy has no psychology at all that we can reach. Like the sea-tides, the tides of these small invaders come, individually as weak and brainless as are drops of water, but collectively as strong as the whole ocean. We cannot oppose that great force when it acts as a unit. We cannot appeal to it or argue with it. Our only chance lies in dividing this enemy; then, perhaps, we may conquer it in detail. "Divide and conquer" every great general has laid down as the great war maxim, and every warrior knows it to be true. Therefore we separate out the common enemy into its several component parts, study each part and specialize ourselves in attacking it in bits. We have, in truth, divided the enemy, redivided and subdivided—as we must, to

conquer—until we ourselves, in the pursuit each of his own enemy section, have become somewhat separated, somewhat divided also, from each other. Those divisions amongst us, let us remember, are of advantage to the enemy, just as division of the enemy is of advantage to us. We have pushed specialized attacks upon different areas of the enemies' front to remarkable perfection, driving notable, and we hope, permanent salients here and there. But what we need now is some great Foch of public health to correlate our forces, to secure better liaison between scattered units, to synchronize and unify our efforts. Then, when we do move, it will be a showdown, perhaps the last great one on earth, between brains and blind persistence, between human study, painstaking insight, forethought and laborious detailed work against surging, penetrating, aggressive numbers—numbers to whom mere reduction will not matter—numbers that can only be really defeated by total extermination. (Howard, "Science," December 30, 1921.)

Public health, then, is prevention, not therapeutics; it is war, not philanthropy; we must divide our enemies in order to conquer them. These are our first three principles.

As in all wars we must build up our own powers and pull down those of our enemy. We do the first through hygiene; the second through sanitation.

What are some of the immediately important divisions of the enemy here and now? From the *racial* standpoint the causes of hereditary feeble-mindedness constitute probably the most ghastly, progressive and alarming problem on the hygienic side; the causes of tuberculosis, the venereal diseases, and other infections, on the sanitation side.

From the *community* standpoint the outstanding need is the war against disease as waged for the coming generation—the supervision of child life, beginning before the child is born and continuing until, as a full-fledged citizen, he joins the adult ranks. This will, of course, include the local phases of the racial items already just stated; it will of course include all the items of hygiene and of sanitation as applied to local problems.

From the *individual* standpoint, immunity against and the

evasion of disease are the chief items that relate to sanitation, while nutrition and activity of body and mind, with proper rest, are the chief advancers of health, the chief items that relate to individual hygiene.

The greatest single thing the individual of today can do to advance his own personal hygiene and sanitation is to secure for himself an annual (or more frequent) medical examination. Thus he will secure medical advice that will make his nutrition and his activities gibe with one another; a medical survey of his body that will detect disease in its early curable stages and so benefit him personally; and incidentally this survey will prevent much spread of infection resulting from otherwise undetected disease now too often developing unheeded until it reaches its infective stages.

One very fine feature of such annual medical examinations is that the detailed examination and specific advice thus given to individuals for their own good first is always also good for the community and for the race as well.

There are a few, a very few, definite rules the individual may follow in his own life for *prevention of disease.* The first of such rules is "the $30,000,000 rule"—"fever calls for bed." This means that any rise of temperature should result in the individual who shows it, quitting work and resting "flat on his back" until the fever goes. The second is like unto it. "Fever and pain together call for the physician"—(and also, either one alone, fever or pain, continuing half a day, calls for the physician as much as both do, when together).

The third great rule of prevention is: "Keep away from the sick." Unless your duty as physician, nurse or attendant calls you to them, you, as a good citizen, have no business with sick people until the physician gives a clean bill—permits approach because the patient has proved not to be infectious. This rule applies obviously enough to smallpox and such like, of course, but it applies to colds, pneumonia and other infections now spread very widely by lack of appreciation that they are infectious.

For *promotion of health* the first great rule is moderation in all things; the second, alternation of activity with rest at

frequent intervals. The third, and this applies mentally and morally, as well as physically, is: "Keep cool!"

Conclusion

Any "short course in public health" is chiefly to be noted for the things it has unavoidably omitted rather than for what it has given to its readers. But if one remembers that public health embraces "all human physical life" one can readily see that all the books yet written cannot fully contain it. Without life study of its details no one can hope to learn more than its chief principles; some of these have been here recorded, briefly and inadequately, but, it is hoped, simply and directly. There are thousands of applications of these principles in every walk of life which could not here be touched on —application to every trade or business or profession, to every age, both sexes, different countries, to farms, villages, cities, to sailors, soldiers, students, housewives, laborers, to camp and court, to school and market place, to palace and hovel, to food, to water and to air, to all our biological associates, to every one of our 411 diseases, and to all their stages, variations and combinations, to normal and abnormal life in every detail. But these definite, specific applications are for the professional. They are only confusing to the nontechnical citizen. If this short course has made the *principles* clear and shown the great machinery of human life, however dimly, as a real definite *mechanism* and not as a mere chaos or a dream, its main objective will have been more or less well reached.

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